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THE JOURNAL

OF THE

FRANKLIN INSTITUTE,

DEVOTED TO

SCIENCE AND THE MECHANIC ARTS.

EDITED BY

Prof. Edwin J. Houston, A.M., Mr. Theo. D. Rand, Prof. Coleman Sellers
E. D., Prof. H. W. Spangler, Mr. S. Lloyd Wiegand, Committee
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INDEX.

Acid, molybdic, action of haloid acids in gas form, upon. (Smith–Oberholtzer), 460
Areas, errors in the determination of, from measured diameters. (Lewis), 83
Artesian wells as a water supply for Philadelphia. (Carter), 58

Battery, closed-circuit, some principles that must be observed in order to make a, and a new portable dry cell, etc. (Northrup), 223, 318
Birkinbine, John. From mine to furnace, 259, 375
Blake pumping engine, duty trials of. (Peabody–Dean), 167, 327

Book Notices:
  Byrne. Highway construction, 161
  Nichols. Useful information, etc., 163
  Houston. Electricity and magnetism, 163
  Léauté. Encyclopédia scientifique, etc., 324
  Jones. Logarithmic tables, 325
  Endlich. Blow-pipe analysis, etc., 326
  Wilson. A manual of irrigation engineering, 474
    Photographic mosaics, 475
  Suplee. The Yale and Towne Manufacturing Company catalogue, 475
  Kapp. Alternating currents, 476
  Hopkinson. Original papers on dynamos, etc., 476
    How to become an engineer, 477
  Baker. Engineers' surveying instruments, 478
  Crocker-Wheeler. Management of dynamos and motors, 478
  Fleming. Alternate current transformer, 478
  Church. Mechanics, 479
  Grant. Treatise on gear wheels, 480
Breed, Mary Bidwell. Phenolphthalein and methylorange as indicators, 312
By-products of coke, utilization of, 17, 34

Carter, Oscar C. Artesian wells as a water supply for Philadelphia, 58
Causes of fire. (Hexamer), 288
Cazin, F. M. F. Resistance to ship's motion, etc., 200, 299, 364
Chemical Section:
  See Franklin Institute.
Closed-circuit battery, some principles that must be observed in making, etc. (Northrup), 223, 318
Coke, change in the physical properties of, made in the by-product ovens. (Fronheiser), 34

Coke industry, development and condition of, by the utilization of the by-products. (Leistikow–Wasmuth), ... 17
Crane, the modern traveling. (Outerbridge), ... 247

D'Arsonval galvanometers, recent improvements in. (Genung), ... 63
Dean, F. W. Duty trials of a pumping engine, built by The Geo. F. Blake Manufacturing Company, for the city of Newton, Mass , ... 327
Dodge, James M. Rope-power transmission, ... 437
DRAWING SCHOOL:
    Annual report of the director, ... 482
Dry cell, portable, described. (Northrup), ... 223, 318

ELECTRICAL SECTION:
    See Franklin Institute.
Errors in the determination of areas from measured diameters. (Lewis), . . . 83
Expert, the scientific, in forensic procedure. (Himes), ... 407

Fires, causes of. (Hexamer), ... 288
FRANKLIN INSTITUTE:
    Annual reports:
        Board of managers and committees, ... 237
        Drawing school, ... 482
    Chemical Section:
        Proceedings of stated meetings, ... 51, 137, 317, 311, 385, 447
    Electrical Section:
        Proceedings of stated meetings, ... 62, 138, 217, 386
    Stated meetings, bulletins, supplements, proceedings, . 88, 164, 246, 326, 405
    Proceedings, ... 485
Fronheiser, Jas. J. Remarks on the changing of the physical properties of coke made in the by-product ovens, ... 34

Galvanometers, d'Arsonval, recent improvements in. (Genung), ... 63
Gas engine, test of a one hundred horse-power, using producer gas. (Spangler), 340
Gauge, Haines' automatic micrometer, for rolling mill work, ... 42
GENTH FREDERICK AUGUSTUS. Memoir of, ... 448
Genung, Nelson H. Recent improvements in d'Arsonval galvanometers, . . . 63
Greene, Wm. H., and Wahl, Wm. H. A new process for the manufacture of manganese on the commercial scale, ... 218
Greene, Wm. H., and Wahl, Wm. H. A new process of reducing metallic oxides, ... 453

Haines, Robt. B., Jr. The Haines automatic micrometer gauge for gauging hot or cold rolling mill work, ... 42
Haupt, Lewis M. The road movement, ... 1
Heliochromoscope, the. (Ives), ... 35
Hexamer, C. J. Causes of fires, ... 288
Himes, Charles F. The scientific expert in forensic procedure, ... 407
Howe, H. M. Manganese steel, ... 114, 191

Ions, migration of the. (Stradling), ... 387
Ives, Fred E. The heliochromoscope, ... 35

Leistikow, B. Development and condition of the coke industry by the utilization of the by-products. (Trans. by Henry A. Wasmuth), ... 17
Lewis, O. T. Errors in the determination of areas from measured diameters, . 83

Manganese, a new process for the commercial manufacture of. (Greene–Wahl), 218
Manganese steel. (Howe), ... 114, 191
Maximum stresses from moving single loads on the members of three-hinged arches. (Werner), ... 45, 129
Metallic oxides, a new process of reducing. (Greene–Wahl), ... 453
Methylorange and phenolphthalein as indicators. (Breed), ... 312
Migration of the ions. (Stradling), ... 387
Mine to furnace, from. (Birkinbine) 259, 375
Molybdic acid, action of the haloid acids in gas form upon. (Smith–Oberholtzer), ... 460

Northrup, E. F. Some principles that must be observed in order to make a good closed-circuit battery, and a new portable dry cell, in which these principles are applied, ... 223, 318
NUGENT, EUGENE. Obituary notice of, ... 385

Oberholtzer, Vickers. (*See* Smith and Oberholtzer.)
OBITUARY NOTICES:
  Frederick Augustus Genth, ... 448
  Eugene Nugent, ... 385
Otto-Hoffmann coke ovens for utilization of by-products. (Leistikow–Wasmuth), 17
Outerbridge, Alex. E., Jr. The modern traveling crane, ... 247

Peabody, Cecil H. Duty trials of a pumping engine, built by The Geo. F. Blake Manufacturing Company for the city of Newton, Mass., ... 167
Pemberton, H., Jr., and Tucker, Geo. P. The deposits of native soda, near Laramie, Wyoming, ... 52
Phenolphthalein and methylorange as indicators. (Breed), ... 312
Photography, Philadelphia's share in the development of. (Sachse), ... 271
Philadelphia's share in the development of photography. (Sachse), ... 271
Priestman, engine, the, as manufactured in America. (Sellers), ... 89
Pumping engine (Blake), duty trials of. (Peabody–Dean), ... 167, 327

Resistance standards and temperature coëfficients. (Willyoung), ... 140
Resistance to ship's motion. (Cazin), ... 200, 299, 364
Road movement, the. (Haupt), ... 1
Rope-power transmission. (Dodge), ... 437

Sachse, Julius F. Philadelphia's share in the development of photography, . . 271
Scientific expert, the, in forensic procedure. (Himes), ... 407
Sellers, Coleman. The Priestman engine as manufactured in America, ... 89
Ship's motion, resistance to. (Cazin), ... 200, 299, 364

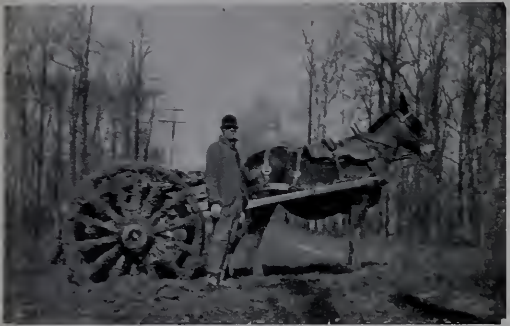
Smith, Edgar F., and Vickers Oberholtzer. Action of the haloid acids in gas form upon molybdic acid, ... 460
Soda, native deposits of, near Laramie, Wyoming. (Pemberton–Tucker), . . . 52
Spangler, H. W. Test of a one hundred horse-power gas engine using producer gas, ... 340
Stradling, George F. Migration of the ions, ... 387

Temperature coëfficients, determination of, etc. (Willyoung), ... 140
Traveling crane, the modern. (Outerbridge), ... 247

Wahl, Wm. H. (*See* Greene–Wahl).
Wasmuth, Henry A. (*See* Leistikow).
Werner, Emerick A. Maximum stresses from moving loads in the members of three-hinged arches, ... 45, 129
Willyoung, Elmer G. Some new apparatus for the most exact comparison and adjustment of resistance standards and the determinations of temperature coëfficients, ... 140

ROAD VIEWS

FROM PHOTOGRAPHS TAKEN CHIEFLY IN THE VICINITY OF PHILADELPHIA.



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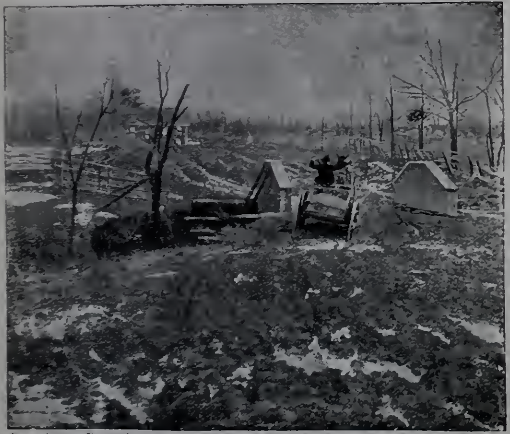

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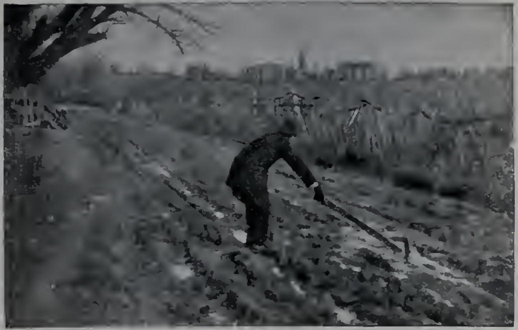

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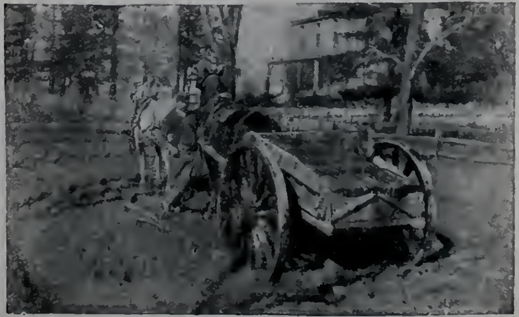

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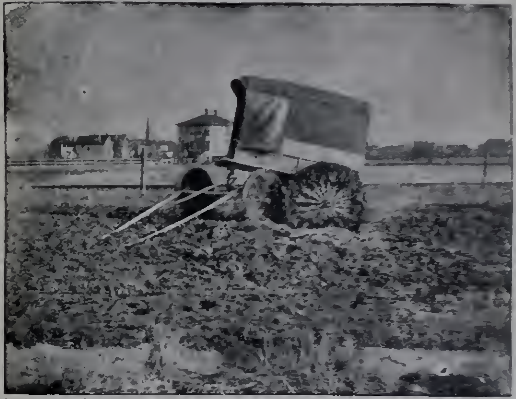

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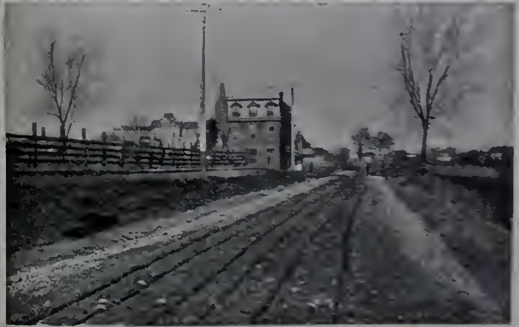

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THE Franklin Institute is not responsible for the statements and opinions advanced by contributors to the *Journal*.

THE ROAD MOVEMENT.

BY LEWIS M. HAUPT, Consulting Engineer.

[*A lecture delivered before the Franklin Institute, November 11, 1892.*]

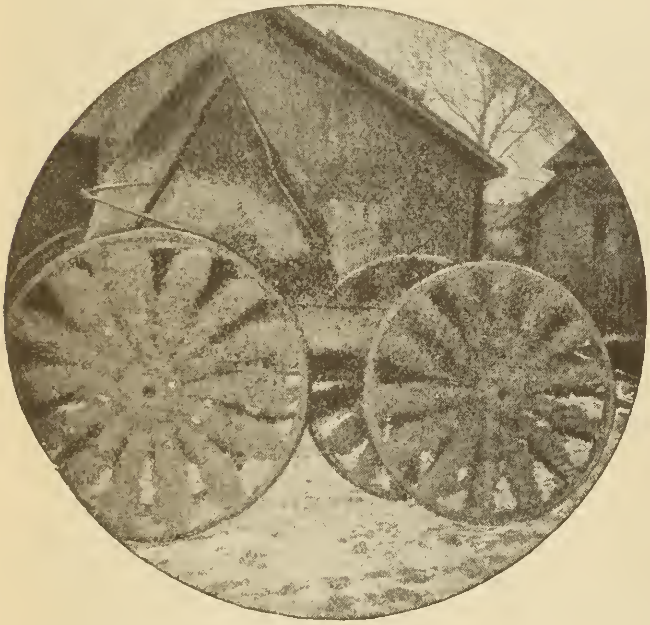
Professor Haupt was introduced by the Secretary of the Institute and spoke as follows:

MEMBERS OF THE INSTITUTE, LADIES AND GENTLEMEN:

Undoubtedly this is an age of improvement, and great strides have been made in adapting the resources of nature to the wants of man, yet if we scan the horizon of progress we will discern certain streams of development extending far beyond the general contour which marks the advance of the arts and sciences, while others may be discovered lagging far within the perimeter of progress, oppressive by their very proximity.

The symmetrical development of our transportation lines, as a system, demands that public interest and attention be concentrated upon those which have not kept pace with the march of improvement, and that they be advanced to a much higher stage of efficiency.

In a previous lecture* on ship canals, attention was directed to the mutual dependence of the ships and the car on the one hand, and the car and the cart on the other, but little was said about the relative cost of movement by this latter mode of conveyance. It was shown that the waterway was by far the most economical for manifest reasons, being as low in some cases as one-twenty-sixth the cost by rail. In attempting to make a comparison between rail and road the question is more complicated because of the greater range of resistance to be overcome in the latter, depending upon grades, character and condition of surface, friction and many other factors, but as it is the earth road which forms the connecting link between the farm and the station it will be taken as a basis of comparison. On an ordinary road, dry and in good condition, the cost of hauling a ton one mile is variously estimated at from fifteen to twenty-five cents on a level. Taking the least cost, fifteen cents, and comparing it with the least cost by rail, say four mills, we see that the cost of movement by road is at least thirty-seven and one-half times greater than by rail. But at certain seasons of the year the limit of this ratio runs up to infinity, as it is impossible to move a load at any cost; and the railways



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* *Vide Franklin Institute Journal*, November, 1892.

that are dependent upon local delivery must side-track a large portion of their rolling stock until Dame Nature comes to the rescue and hardens the road, either by a drying or freezing process. Taking the extremes, therefore, we find the cost of the ton-mile on land may be 900 times that on water, and the importance of improving the roads become impressive as an economic problem. It is not surprising that the farmers complain. Various estimates have been made of the saving due to even a slight improvement of the surface, so as to enable three horses to do the work of four. In Great Britain this economy has been placed at $100,000,000 per annum.

From "GOOD ROADS."

The cost of keeping a horse is stated to be about $125 a year; this would, therefore, represent the tax which is imposed upon the owners of teams by the failure to improve the road surface to such an extent as to dispense with one horse.

On the portion of the farm products of Pennsylvania which is sent to market, the difference between the cost of hauling on a clay or on a macadam road is over $200,000 per annum. Were this amount expended by the State in permanently improving the roads, it would not be long before the people of the State would be that much better off and the price to the consumer would be reduced, while the producer would have as large or even a larger margin on his products. To move the hay crop alone caused a loss of $1,560,000, while the total loss due to bad roads aggregates not less than $6,000,000, or the interest on $100,000,000.

At a recent agricultural convention it was stated that, "In the last fifty years $200,000,000 had been spent on roads in Pennsylvania and that $7,000,000 are now spent annually with nothing to show for it." "At the high rate of $10,000 per mile this would macadamize about 700 miles or ten miles in each county. This large sum is lost each year in throwing clay into the road, which works back to clog up the ditches."

Roads should be built continuously and not in patches. Work should be conducted at all seasons and not be made subservient to other interests, when it may suit the convenience of the taxpayer to work out his dues. Their locations and grades should be revised to meet the requirements of the amount and kind of traffic passing on them. They should have continuous and systematic supervision. These and many other conditions should be fulfilled that we may remove the wasteful and disgraceful condition of our highways and greatly increase their utility and the economy of transporting the almost unlimited resources of this great Commonwealth over them.

In looking for the cause of the neglected condition of our highway system, we find it to result largely from the ignorance prevailing amongst agriculturalists as to the economy of good roads, and the mistrust lest a money tax may be appropriated to some other purpose or disappear in the pocket of dishonest officials. As the rural districts have a large representation who desire to conform to the wishes of their constituents, it becomes difficult to secure the passage of any law which would radically change for the better our methods of building and repairing roads without their sanction. On this point, our esteemed ex-Governor, Hon. James A. Beaver,* in his paper, entitled "Why we have so Few Good Roads," recently said: "The main difficulty in the case is perhaps to be found * * * in the indifference of the general public upon the subject."

Yet, "most people are interested in securing a better condition of the common roads of the country for their own convenience and pleasure. But the disposition to antagonize a forward movement in this respect, or to retard an intelligent and comprehensive administration of present laws, is based perhaps upon the fear of the amount of money necessary to be expended in securing, in the first instance, a thoroughly good road. In all discussions of the subject, this seems to be the final resort of those who oppose improvements upon the present system."

This objection is not limited to roads, but is the battle cry of obstructionists generally. The "great cost" of a project is the *bête noir* of many an urgent and important public work, and the fear of increased taxes has sounded the death-knell of many an improvement which would have lightened the burdens of the community and added greatly to the pleasures and comforts of life.

The cost of even the grandest of public works, however great, if honestly administered, will be returned to the taxpayer many-fold. In our own city we have excessive wear and tear from ruinous pavement which under a wise and systematic administration are being gradually removed, but still there are other works quite as necessary restrained on the same plea of too great cost; *e. g.*, the boulevard, the harbor front and the water supply, for each and all of which there is an urgent demand that Philadelphia may maintain her honored position as one of the foremost cities of civilization. But the conservatism which forces us into the old footpathway of our forefathers retards our rapid movements and condemns us to the wear and tear of the tread-mill.

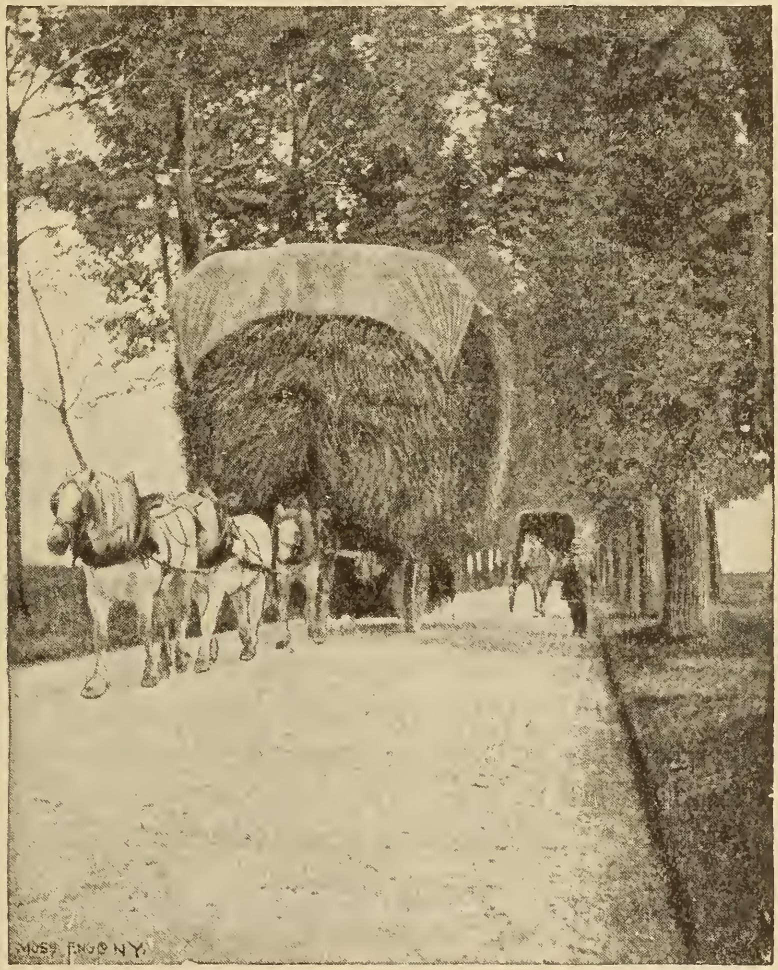
Continuing, Governor Beaver adds: "We are satisfied, or if not satisfied with, we endure the system, or lack of system, under which our forefathers blazed their roads through the primitive forests and made their contributions to their maintenance by a few days' work in each year, which caused them to be more impassable than they were the year before." * * * "A good road is cheaper than a poor one, but prejudice, opposition to change and indifference control the masses of our people and dictate the course of legislation. If we are to secure the best results, it is undoubtedly true that we must change the laws enacted fifty or 100 years ago so as to meet present needs and conditions. One of the difficulties in securing a change in our present laws is found in the importance of the subject, which has attracted so much attention, that many of our law-makers have plans and codes of their own which they are unwilling to exchange for those of another."

---

* *The Forum*, August, 1892, "Why we have so Few Good Roads."

"Any simple plan which will secure the location of a road (or its revision) by a competent civil engineer, and its construction by a man who is familiar with the principles of road making and is able to give to the community 100 cents for every dollar expended, will reach the results at present desirable and attainable. With us in Pennsylvania the fundamental defect in our law is the right which is given to the taxpayer to 'work out his road tax.' The result of this system is that repairs are made when they are least needed and the smallest amount of work for the largest amount of pay possible is secured." * * "In general our roads are located by those who have no enlarged experience in engineering and who prefer to accommodate their neighbors by following the property lines between them, or making the road near or distant as may suit their convenience rather than to consult the general good of the public."

Governor Beaver then goes on to say that the essentials of a good road are, first, a good location; second, a good foundation; and third, a firm and durable superstructure; and that these may only be obtained at some cost, such as any prudent business man would make to secure permanency and economy in his business affairs. That no radical reform can be expected to be carried out in a day, but that progress may be made by taking one step forward each time. Quoting again, he says: "If in Pennsylvania and elsewhere, where the system of working out the road tax prevails, we could secure a simple amendment which would compel all taxes for road purposes to be paid in money, as other taxes are paid, and if that money tax were expended in each municipality by one man of good common sense, we could in a very few years prepare our people for another step forward." Yet a bill embodying these and other features failed to become a law at the last session of the Legislature.



From "Good Roads."

Further, as to the assertion that the railroads have supplanted common roads and rendered them unnecessary, it is quite the reverse since the farmer, who was formerly so remote that he could not market his excess of products without converting it into live stock which could transport itself, can now in most cases reach a station and there ship by rail at greater profit to himself and benefit to the railroad; but to avoid a glut in the market the road should be made passable at all seasons of the year. This would steady prices and cheapen supplies by saving the wear and tear as well as uncertainties of transportation without reducing the price at the farm.

Several agricultural societies in this State have passed resolutions denouncing turnpikes and instructing their representatives to vote against them on general principles. This action is easily understood when the reasons are stated. The experience of the counties referred to is unfortunate, in the fact that many years ago some stock companies were authorized to build pikes and levy tolls without sufficient restrictions as to their maintenance. In consequence pikes were built in the old-fashioned way which in a short time became almost impassable from the neglect to maintain the metalling in good condition while the tolls were collected as usual. The consequence is that the stockholders do not want the State to step in and break up their monopolies by making free turnpikes, which would be kept in order and take their patronage, while the farmers believing that they would be taxed still more heavily to maintain some political sinecures, conclude it is better rather "to endure the ills they have than fly to others that they know not of." Such, then, are the practical difficulties in the way of securing legislation. It is necessary to convince the farmer that he will be benefited, his taxes be lowered and his property be brought nearer to the market in both time and distance before much progress can be made. This is being done in the best possible manner by the various townships near our larger cities in constructing macadamized roads in these sections. Gradually the work goes on and the contagion is spreading to the more remote and sparsely settled districts, but here the cost per capita is too great and the State should be allowed to assist. In fact, there are some roads in the State which, from the peculiar physical conditions surrounding them, are of no use to and cannot be used by the people living in the townships which they traverse. I refer to those highways skirting the base of a mountain on the one hand and a river on the other. This grand old Keystone State, so rich in resources, so progressive in manufactures, agriculture and commerce, so well provided with railroads, and so free from debt, is unfortunately hampered with a broken topography, intersected by as miserable a system of roads as can well be found in any State of the Union. It was my misfortune, a few years since, to have to travel on the "turnpike" from Lancaster to New Holland, about ten miles, in the regular stage. It should have been traversed in 100 minutes but it took 300, and the pike was said to be in "good condition." Ten miles in five hours was the rate. A good walker could cover twice the distance in the same time. I found it much pleasanter to walk than to ride. The irregularities of the road between Harrisburg, the capital, and Gettysburg, the college, which I traversed in a stage some forty-odd years ago, are still indented upon my cerebral chronograph so deeply that I have ever since been "stage-struck."

Yet when it is seriously proposed to soften the asperities of life and mend our ways by the application of science and common sense, we are repulsed with the invincible argument that our grandfathers endured these hardships and it made them tough and manly, why should not we and our children follow in the same rut?

Against such an opinion arguments are unavailing, for

"The man convinced against his will,
Retains the same conviction still."

But the road movement is growing and gaining in favor and popularity, and there is no organization that has done so much as a body to promote it as the "*wheelmen*." A hard and smooth road surface is to them what air is to a bird or water to a ship, and yet it is no more essential to the cyclist than to the agriculturalist, the only difference being that the former supplies his own power and hence knows its value, while the latter simply holds the reins and whip which propel and control his animal motor.

If the teamster attempted to pull his own truck he would be convinced of the difference in resistance between a mud road and a macadamized pike in ten minutes, and you could not drive him off the pike if the tolls were made a dollar where they are now a cent.

In reviewing and summing up the opinions advanced by the competitors for road prizes, recently offered by a committee of our public-spirited citizens, and published under the title of *A Move for Better Roads*,* I concluded "there are serious objections to the stock company proposition, as it prevents uniformity of action and equitable taxation. Some roads will cost less and be taxed more than others, and it is always difficult to enforce a standard as to the condition of the highways or to compel companies to maintain it.

"The plan which commends itself to the writer as being the simplest, the most direct and least objectionable, is that of State aid under proper restrictions. For example, let the amount desired be voted for the construction (not maintenance) of permanent roads, to be divided pro rata amongst the counties making appropriations from their own funds for a similar purpose. * * * No public work of this kind should be undertaken until a competent civil engineer is appointed to represent the interests of the State, who should carefully revise the character and location of every road before the work of metalling the surface is authorized. The economy effected by this plan will soon save far more than the expenses of the office in cost of maintaining the roads, and the indirect benefits by reduction of tractive force would be incalculable. The best is the cheapest in this case, and it is well said that "the man who works for nothing is not worth his board." While other States find it to their interest to maintain an engineer, Pennsylvania has been and is content to entrust the supervision of her public works to the rotation of a political office, and suffer accordingly from indifference and neglect. Upon this point a well-known authority, in commenting upon the changes so frequently made in our public service, said, "Men dealing with interests so vast should not be subject to constant changes. Change of Commissioners means change of methods, and change of methods during the prosecution of engineering works is very likely to mean disaster."

---

* Wm. H. Rhawn, Chairman, Philadelphia. H. C. Baird & Co., 810 Walnut Street, Philadelphia, publishers.

I am well aware that there is serious objection to State aid, but it arises from the lack of patriotism, so prevalent in times of peace, and the fear lest some one section may be unduly favored at the expense of another. There is the further plea that it is unconstitutional, the last resort of a man or a party without an argument when he is opposing an appropriation of public works. But this is answered by quoting the words of the revered Thomas Jefferson, whose house stood but a stone's throw from this Institute, and who aided in framing the Constitution. He said that the *imposts should be maintained, and that the surplus created should be appropriated to the improvement of roads, canals, rivers and education.* He placed roads first and education last, perhaps having in mind the maxim that there is no royal road to

From "GOOD ROADS."

learning, and thinking it necessary to provide the way first, knowing that the education would follow.

In these days the order seems to be reversed, as education must now precede road construction and legislation.

Again it is decreed in Article I, Section VIII of the Constitution, "Congress shall have power to establish post offices and post roads," whereby jurisdiction is clearly vested in the Federal Government to undertake the construction of roads and the regulation of interstate commerce, even more explicitly than for the improvements of rivers and harbors.

Under and by virtue of this authority the Government has already vested large sums of money in the construction of military and post roads, and in subsidies and bounties to railroads and transportation companies to encourage and stimulate intercommunication.

At the recent meeting of the League of American Wheelmen in Washington, prior to the close of the first session of this Fifty-second Congress, resolutions were adopted calling upon that body to create a highway commission to consider the question of the extension of national highways, and the granting of Government aid in their construction. This movement seems to be the centralization of the efforts which are making in almost every State and Territory of the Union for the improvement of our roads. And it has been focused in the passage of a bill through the Senate providing for a commission consisting of two Senators, five members of the House of Representatives, and five citizens to be appointed by the President of the United States, making twelve in all, whose duty it shall be to frame a measure looking to the best method of securing and encouraging some systematic plan for the general improvement of our highways.

The bill creating this commission is expected to pass the House early in the coming session, and become a law without a dissenting vote. The promoters of this movement called a meeting at the opening of the Columbian Exhibition, October 21st, at which the representatives of the various States and local societies, Boards of Trade, Chambers of Commerce, Farmers Association, Leagues of American Wheelmen and all other public or private bodies interested in road improvements were invited to be present to effect a preliminary organization for a National League.*

At this meeting, with over 1,000 persons present, a temporary organization was effected, consisting of Hon. Chas. F. Manderson, U. S. Senator from Nebraska, President; Gen. Roy Stone, Vice-President and Secretary; and our esteemed fellow-citizen, Mr. Wm. H. Rhawn, President of the National Bank of the Republic, Treasurer.

Ten directors were also selected from amongst our distinguished and patriotic citizens. They are men of so great weight and influence that the mere recital of their names is an earnest endorsement of the movement with which they are thus identified. The directors are:

Hon. E. H. Thayer, of Iowa; Philip D. Armour, of Illinois; Leland Stanford, of California; Clem. Studebaker, of Indiana; Samuel W. Allerton, of Illinois; Chauncey B.

---

* The signers to the call were:

E. H. Thayer, President Iowa State Road Improvement Association.
Fredk. Fraley, President National Board of Trade, Philadelphia.
P. S. Townsend, Chairman Committee on Roads, National Board of Trade.
Lewis M. Haupt, C. E., Secretary Committee on Better Roads, Editor of *A Move for Better Roads*.
Hon. S. M. Cullom, U. S. Senate (Illinois), Chairman Committee on Interstate Commerce.
Hon. Chauncy B. Ripley, Vice-President New Jersey State Road Board.
Hon. P. S. Post, M. C., Illinois.
Hon. Chas. F. Manderson, U. S. Senate (Nebraska).
Isaac B. Potter, Chairman Committee on Improvements of Highways, Law Secretary New York State Roads Improvement Association.
Chas. Q. Eldridge, Secretary Board of Trade, Hoosick Falls, N. Y.
Albert G. Porter, Indiana.
Clem. Studebaker, Indiana.
Hon. Dan. Waugh, M. C., Indiana.
Wm. P. Dillingham, Vermont.
Leavitt Hunt, Vermont.
Hiram A. Huse, Vermont.
Edward Browning, Pennsylvania.
Wm. A. Stone, M. C., Pennsylvania.
Roy Stone, New York.
J. H. Fisher, Secretary Committee on Roads National Board of Trade.

Ripley, of New Jersey; Alexander J. Cassatt, of Pennsylvania; W. Seward Webb, of New York; Col. Albert A. Pope, of Massachusetts; Chas. L. Burdett, of Connecticut.

The name of this organization is the National League for Good Roads, a name sufficiently suggestive of its purposes and the composition of its board is a guarantee that good results will follow.

The permanent chairman is now Hon. E. H. Thayer, President of the Iowa State Roads Improvement Association, and S. K. Thornton Prime, of Dwight, Ill., Secretary.

Time does not permit me to refer specifically to the indefatigable work of Col. A. A. Pope, of Boston, in his efforts to aid this movement in every conceivable way, and his excellent practical suggestions and liberal endowment of a chair for instruction in road construction, nor to the admir-

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Thos. Sturgis, Secretary Committee on Roads, "New York Farmers," New York City.
Edward Burrough, President State Board of Agriculture, New Jersey.
Franklyn Dye, Secretary Road Improvement Association of New Jersey.
Ambrose Snow, President New York Board of Trade and Transportation, New York City.
Horace Porter, New York.
F. B. Thurber, New York.
Hon. Walter I. Hayes, M. C., Iowa.
Chas. W. Stone, M. C., Pennsylvania.
Hamilton A. Hill, Secretary National Board of Trade, Boston.
Levi Chubbuch, Secretary Missouri State Board of Agriculture.
Lucius Fairchild, Wisconsin.
J. A. Potts, President Missouri State Board of Agriculture.
Edward D. Porter, Dean College of Agriculture.
J. S. Hull, *et. al.*, Commissioner of Erie County, Ohio.
Millard F. Lane, Chairman Committee on Roads National Carriage Builders' Association.
J. L. Erwin, President Missouri Road Improvement Association.
J. K. Gwinn, Ex-Commissioner Missouri World Fair Board.
Norman J. Coleman, St. Louis.
Geo. Longman, St. Louis.
C. D. Coleman, St. Louis.
J. W. Hodgkin, St. Louis.
J. P. Blake, St. Louis.
G. L. Whidby, Secretary Georgia Road Congress.
W. L. Wehr, Chairman State Highway Committee of Michigan.

able object lessons which are so largely disseminated through the practical periodical, entitled *Good Roads*, published by Mr. Isaac B. Potter, of New York, nor to the general interest manifested in this subject by numerous engineering, technical and trade journals, which are full of terse and practical articles on the subject. In fact, the awakening is general, and no legislator need feel that the press is lukewarm on this subject, or that it will call him to account for sustaining any revision of the law which will improve the condition of our common roads. The provisions to this end are briefly these:

From "GOOD ROADS."

(1) Abolish the system of working out the road tax and collect it in cash like any other, paying the laborer in legal tender.

(2) Provide for a revision of the grades and alignment of all roads which are to be made "permanent" by metalling, by placing them under the supervision of a competent engineer.

(3) Regulate the width of tire and length of axles so as to convert the wheels of heavy vehicles into road preservers instead of road destroyers.

(4) Require constant supervision and attention by road-

men regularly employed to maintain the structure in the best possible condition at all seasons of the year.

This does not require that the road should be metalled where stone is scarce, but a man who understands his business will soon learn how to prepare an earth surface so as to obtain from it the best service.

These few requirements embodied in a law would effect a remarkable difference in the efficiency of our road surfaces and great economy in their maintenance. To secure such modification, however, it becomes the duty of everyone interested in the subject of good roads (and who is not?) to impress upon his representative in the State or National Legislature, by letter or by personal solicitation, the importance of taking some action looking to the revision of the road laws and providing for improvements in their condition, otherwise, "what is everybody's business becomes nobody's business," and the roads remain impassable quagmires for a large portion of the year. Concentration of effort is as necessary in this matter as in any other great undertaking, and unless every citizen will bring his influence to bear at the State capital but little can be expected in behalf of these interests.

As words are inadequate to convey correct impressions of actual physical conditions, let us look at some photographs of good and bad roads collected from Norway, Switzerland, Germany and Ireland, and contrast them with some of the mud roads of our own country. They will serve to impress the importance of the theme upon any who may still have doubts as to the utility of good, hard-surfaced roads.

[The lecture closed with an exhibition of some fifty striking photographs. The illustrations printed in the text (except the first) are typical European roads. The frontispiece needs no explanation.]

DEVELOPMENT AND CONDITION OF THE COKE INDUSTRY BY THE UTILIZATION OF BY-PRODUCTS.

By B. Leistikow,
General Director of the Wilhelms Factory at Enlau, Wilhelmshuette.

Translated by Henry A. Wasmuth, M. E.

[*Address at the fifth meeting of the German Mining Engineers, held at Breslau, September 5, 1892.*]

Industrial innovations, promising considerable profits, as a rule are introduced eagerly and soon become common property. This cannot be claimed of a branch industry, the distillation of coal with saving of by-products, of which I will treat especially to-day.

The distillation of coal consists in the carbonization of coal in closed chambers, *i. e.*, the expulsion of volatile matter by heat externally applied. The remaining solid residue, carbon, is termed coke.

The object of the dry distillation of coal is twofold, according as the volatile matter or the solid constituents are considered as principal products. The yield of volatile matter as principal product is the object of the manufacture of illuminating gas, and the remaining solid constituents are by-products. The gain of the solid constituents by the distillation of coal is the object of the manufacture of coke and the products of volatile matter are saved as by-products.

I will treat the saving of these by-products of the coke industry and its development, illustrating the subject by means of drawings furnished by Dr. C. Otto & Co., of Dahlhausen, Germany.

With the introduction of the manufacture of illuminating gas about 1820, was connected also from the beginning the gain of tar and ammonia, but the rational saving of these by-products of the coke industry is of a later date, for no material results had been attained ten years ago. Per haps, the reason has been that, on account of moderate competition, the value of coal and coke was greater and there was little inducement to seek for higher profits, to be realized by costly experiments, and this indifference was strengthened by the erroneous opinion that obtained, that the quality of coke was impaired in the process of saving by-products.

The oldest reports of saving tar from coke ovens date from 1768, and according to those reports so called muffle ovens and also coke ovens were in operation, by which tar was saved, at Sulzbach near Saarbruecken. But it seems that those first trials were not successful.

Archibald Cochrane, Earl of Dundonald, obtained a patent in 1781 to gain tar, volatile oils, alkali, acids, pitch and coke from coal by the combustion of the coal itself, without external heating. This first trial in England also was without success.

Knab in Commentry, Department Allier, France, erected a group of coke ovens with saving of by-products in 1856 and adopted for them the apparatus similar to that used in the manufacture of illuminating gas. The ovens were 2 metres wide, 1 metre high, 7 metres long, and with bottom heating. The gases, deprived of tar and ammonia were conducted back to the ovens, still in use to-day, and burned under the bottoms of the ovens. A comparison of the results obtained by Knab with those obtained to-day shows that the former were insufficient, principally on account of the considerable width of the ovens, and partly due to the quality of the coal. Such ovens, it is said, are still in operation at Flênn near Mons. The priority of Knab is contested, for it is reported that fifty ovens of the Powels-Dubochet system were in operation near Saarbruecken in 1854; the by-products were not saved, for the products of distillation were burned under the ovens. The ovens were only designed to gain a higher percentage of coke, for the carbonization took place in air-tight closed chambers. Such ovens were also in operation at La Villette, Department Seine, in 1860, producing an excellent furnace coke, besides a poor gas, which was mixed with rich gas from the usual gas retorts. As the gas was used for illumination it is obvious that tar and ammonia must have been condensed.

Patents were obtained by Jones and Blackwell in 1861 to save tar and ammonia water by coking coal in piles, but without success. The Knab ovens were improved substantially by Carves in 1862, by heating besides the bottoms, also the side walls by flues. The gases from the air-tight closed ovens were exhausted, and cooled, and conducted to coke scrubbers to be deprived of tar and ammonia, and then to be used for heating the ovens.

Fifty-three Knab-Carves ovens were erected at Bessêge, Department Gard in 1873, and 100 ovens at Terrenoire near St. Etienne, Department Loire, in 1879. After many experiments the ovens were given a width of only 0·6 metre, in order to cause a better penetration of the heat. The gases from the coking process, deprived of tar and ammonia, were conducted to a small grate by a tube and here consumed. The combustion products pass under the bottoms of the coke ovens, ascend to the upper of the three side flues, and finally descend through the side flues into the main canal and to the chimney.

The construction of the Knab-Carves ovens was adopted by Albert Huessener for the construction of a coal distillation plant at Bulmke, near Gelsenkirchen, and to this gentleman is due the credit of being the pioneer for saving by-products of the coke industry in Germany. Huessener first erected 100 ovens with coal distillation in Germany in 1881, and demonstrated that this industry could be made successful.

Numerous new constructions succeeded each other, but not all of them were well received, especially because the prejudice, already mentioned, that the quality of coke was impaired by the exhaustion of gas, was hard to overcome. There was also a general apprehension that German coal in comparatively cold running ovens would furnish a bad coke.

The credit of overcoming these prejudices and of constructing and introducing an oven which meets the highest requirements, is due to Dr. C. Otto & Co., of Dahlhausen on the Ruhr, and especially to Dr. Otto of the firm, who fortunately is enabled to speak here instead of myself, as the foremost representative of this industry; and who, by the erection of ten trial ovens at Holland Mine, November, 1881, laid the foundation of a common system very widely introduced to-day. The oven was perfected by the combination of of Siemens regenerators, patented by Gustav Hoffmann, Superintendent of the Silesian Coal and Coke Works, at Gottesberg, with the Dr. Otto system, and the first ten trial ovens were put in operation at the Carl-Georg-Victor Mine near Gottesberg, in 1883, by Director Berndt, who has been prominent in the introduction of coal distillation.

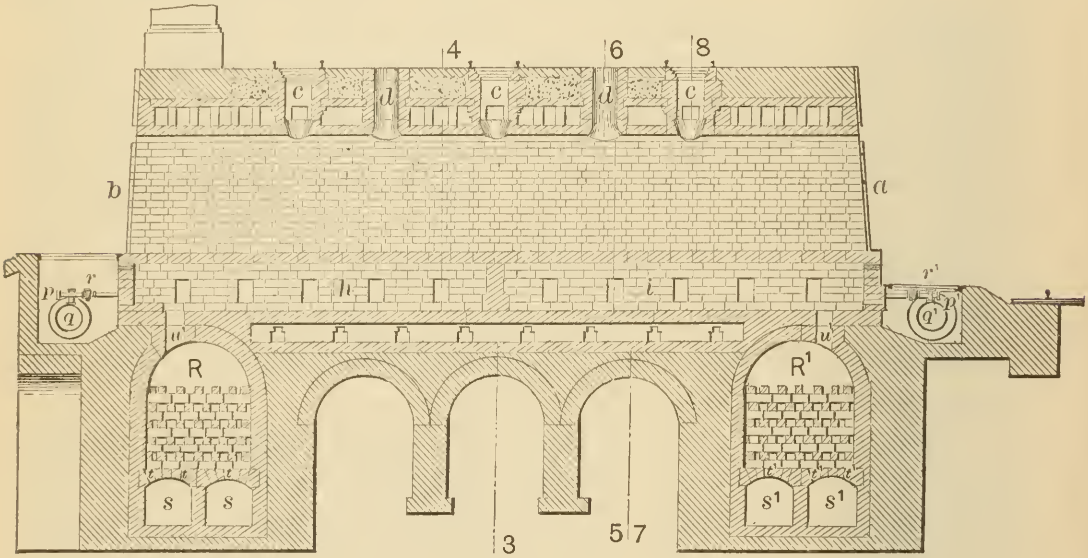

Fig. 1.

This combination, which I will term Otto-Hoffmann oven hereafter, embraces small chambers of 0·4 to 0·6 metre wide, about 10 metres long and 1·6 to 1·7 metres high to the counter-pillar, closed air-tight by doors on both ends. The construction of these ovens is based on the combination of Siemens regenerators by Hoffmann with the common Otto oven, perfected by numerous improvements from time to time. In May, 1886, there were in operation 500 such ovens, of which 330 were in Westphalia, 110 in Silesia, and 60 in Austria, each oven coking about 1,000 tons of coal per annum, yielding, without regard of the varying yield of some brands of coal, 750 tons of coke, thirty tons of tar and ten tons of ammonia.

Fig. 1 shows a longitudinal section of a Otto-Hoffmann coke oven, the pusher being located at the end *a*, while the coke is delivered at the end *b*, where it is quenched. Instead of the openings of the common Coppée oven, by which the gases of the coking chamber first enter the vertical flues of the side walls and then pass into the bottom canals to be consumed, there is no direct connection between the coking chamber and the interior of the side walls. In the arch of the oven are three openings *c*, to charge the oven, and two openings *d* by which the gases of the coking process escape. In the side walls below the counterpillar is located a horizontal flue *e*, *Fig. 2*, by which all vertical flues are connected. The length of the bottom canal *f* is partitioned by a wall into two equal parts *h* and *i*. Each of these halves is in connection with a regenerator *R* or *R′*, respectively, in which the air necessary for the combustion of gas is heated. Further, the pipes *p* and *p′*, fed by gas-distributing pipes *q* and *q′*, enter one-half of the bottom canal, respectively.

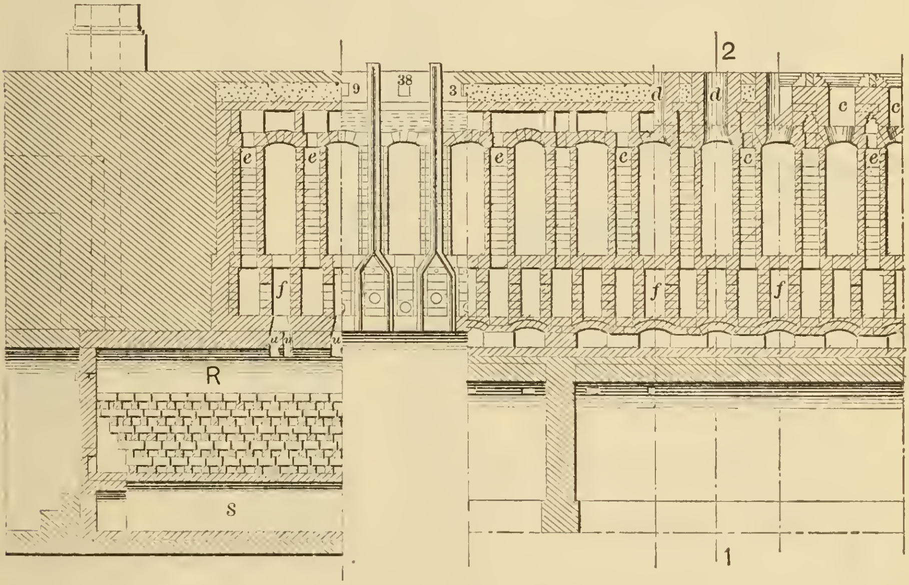

Fig. 2.—Section of oven.

The regenerators are long canals, latticed by bricks, running transversely beneath all chambers. At one end they

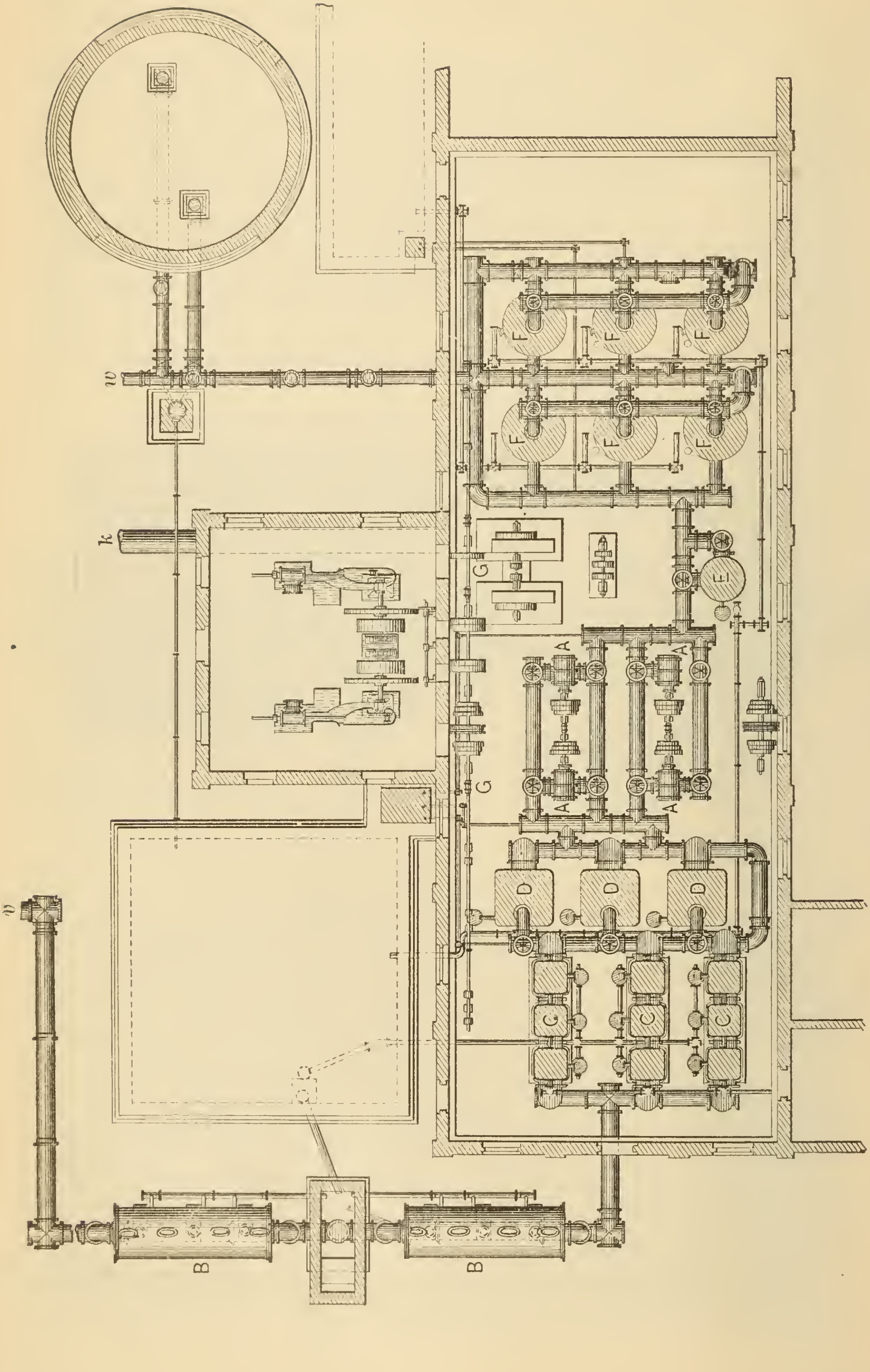

FIG. 3.—Plan of condensation plant.

are in connection by an adjusting trap either with the air-distributing pipe *k*, *Fig. 3*, or backwards with the chimney. As soon as the oven is heated and the coking process is in progress, the gases of the coal escape by the openings *d* into the stand-pipes, similar to those attached to the retorts of gas works, and from there by an open valve into the gas receiver, whence they are conducted by conducting pipe *v*, *Fig. 3*, to the condensation. Here the gas is deprived of the by-products, tar, ammonia and benzole, and then conducted back to the ovens.

Before we describe the condensation we will explain the operation of the ovens by *Figs. 1* and *2*. Assuming that the ovens are in operation, then the gases are conducted to the condensation, as already described, and back to the ovens by pipe line, *Fig. 3*. There is an adjusting trap in the return pipe line by which, according to the position of the trap, the gas enters into gas-distributing pipes *q* or *q'*. If the gas enters into pipe *q* and from here through cock *r* of pipe *p* into the bottom canal *h*, then the trap of the air-distributing pipe is so adjusted that the air enters into the air-distributing canals *s*, *Fig. 1;* thence by small openings *t* in the arch into regenerator *R*, where it is heated and then by slits *u* also enters into bottom canal *h*. In this bottom flue the combustion takes place. The hot products of combustion ascend by the vertical flues of the side walls into horizontal flue *e*, and descending pass through the vertical flues of the other half into bottom section *i*, and from there by slits *a* into regenerator *R'*, heat the canal, pass by the small openings *t'* into canals *s'*, and from here by the adjusting trap into the chimney. After a certain time the adjusting traps are reversed and the gas take a reversed course. Originally it was intended (and also executed by the first plants) to heat the air and also the gas by a second regenerator, located at each end of the ovens. This second regenerator has been abandoned, for it was considered more important to heat the ten times greater quantity of air to a high temperature than to heat also a comparatively small quantity of gas and besides to risk dangerous explosions.

In all later plants there is only one regenerator on each side of the ovens, shown by the accompanying drawings, and the Otto-Hoffmann oven has been simplified considerably by this device and without impairing its efficiency.

The air is heated in the regenerator to about 1,000° C. and it is due to this heating that only a part of the gas is required to heat the ovens, and a considerable quantity is at disposal for other purposes.

I will now try to give a general survey of the arrangements of the condensation plant, shown by *Figs. 3, 4* and *5.*

When the gas generated in the ovens has entered the receiver by the valves it is drawn through the apparatus by exhauster *A*. In this course are inserted several arrangements, for instance, two coal-dust separators *B* cooled by air, in which the greater part of the tar contained in the gas, and also the coal-dust forced along, precipitate, thus reducing clogging of the apparatus by the latter.

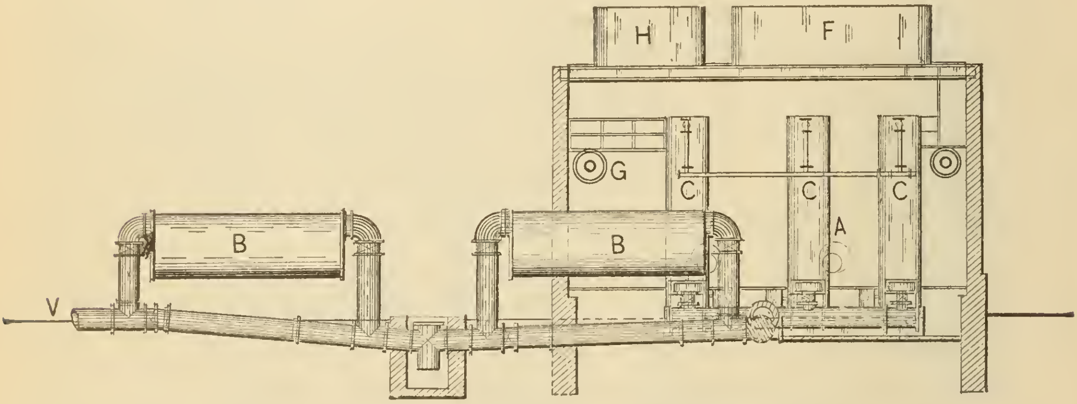

FIG. 4.—Side elevation of condensation plant.

The gas then enters into condensers *C*; square, vertical and riveted boxes in which are fastened a number of wrought-iron pipes through which runs the cool water. The gases ascend around the pipes, while the products of condensation, tar and ammonia water, run off continually at the bottom.

After the gas has passed the coolers it enters into the first scrubbers *D*; these are square and the gas is distributed over a number of pipes which are dipped into water. The gas is first washed in this apparatus by weak ammonia

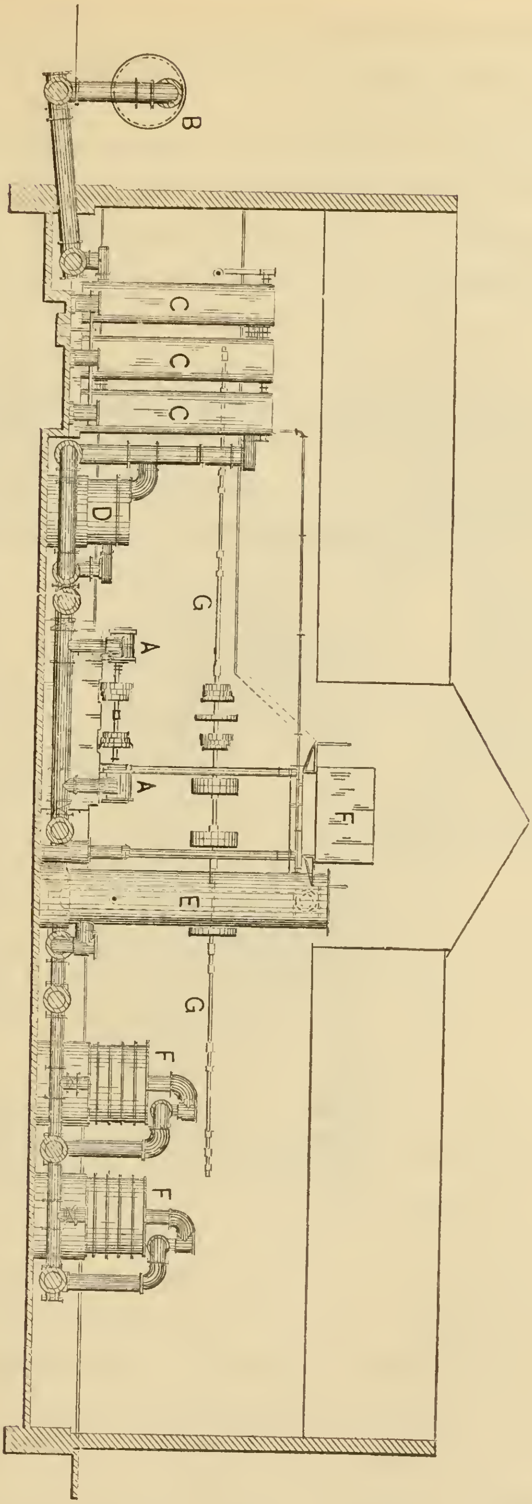

FIG. 5.—Elevation of condensation plant.

water in order to enrich the latter, by which also tar precipitates. The apparatus is so constructed that the water continuously enters at the top and runs off at the bottom.

This water and also the products of condensation of the air and water coolers run into a large cistern, in which tar and ammonia water precipitate.

The exhausters *A* have been aspirating till now and from here the gas is forced by them.

The temperature of the gas increases a few degrees by the rapid compression in the exhausters and, therefore, it is conducted through coolers *E* to lower the temperature possibly to 13–18° C., according to the temperature of the cooling water. After the gas has passed the coolers *E* it enters into the bell-washers *F*. The gas enters at the foot of the apparatus and is distributed to a number of bells, the lower rim of which is toothed and immersed in water, and is forced through the teeth, thus coming into intimate contact with the water. The washers contain four to six stories if necessary, and the water flows from above downwards. The gas flows in the contrary direction and is always

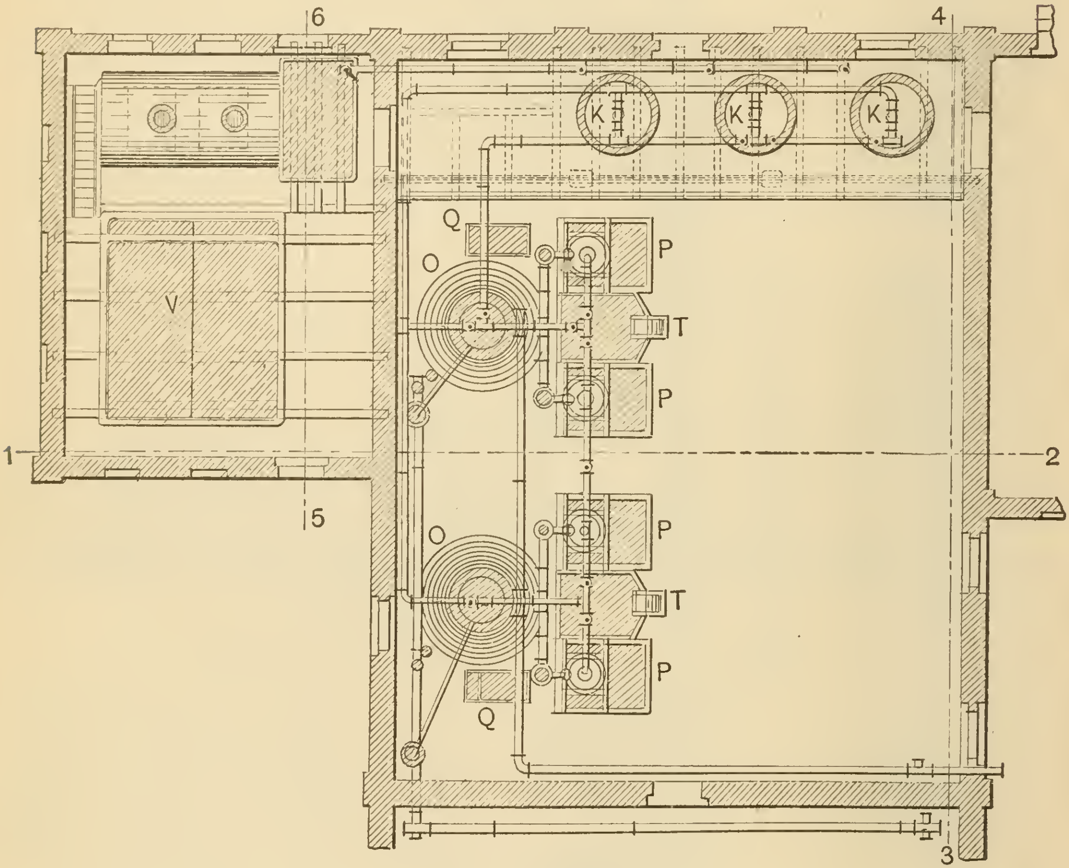

FIG. 6.—Plan.

forced against the fresh water, by which all the ammonia and the rest of the tar are precipitated completely.

The gas, deprived of tar and ammonia, can now be conducted to the ovens to be consumed, if it should not be prefered to remove other products of the gas, as benzole, which is done by special methods. Quite a number of such plants are in operation, but the operators treat the manufacture of benzole as a secret.

Before the gases from the condensation enter into the distributing pipes *g* and *g′* by the adjusting traps, it has to pass a small gas tank, acting as a stand-pipe, to regulate the pressure of the gas, and its principal object is always to show conspicuously to the supervising officer the pressure of the gas exactly, for the temperature of the ovens can be kept uniform only by maintaining a constant pressure. Temperature measurements by the pyrometer of Steinle & Hartung, controlled by metal compositions, indicated in :

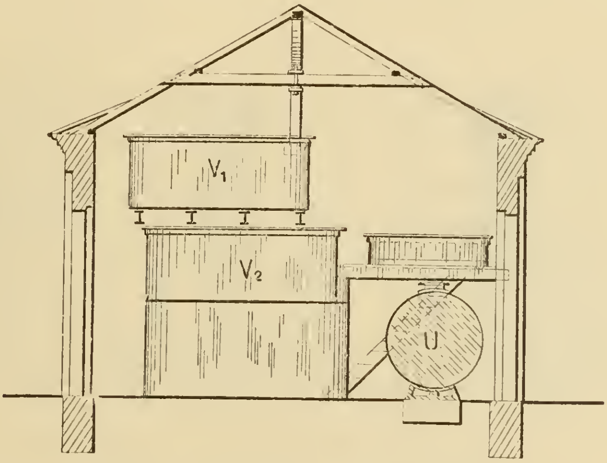

FIG. 7.—Section 5-6 of plan.

The bottom canal, ...	1,200° to 1,400° C.
Side walls, ...	1,100° to 1,200° C.
Regenerators at the beginning of air inlet, ...	1,000° C.
Regenerators at their ends, ...	720° C,
Chimney, ...	420° C.

The tar from the distillation, separated by specific gravity in cisterns is pumped into tank *H*, *Fig. 4*, by a pump located on the wall, driven by shaft *G*, and then it is tapped into tank cars to be shipped to the tar distillation works.

The ammonia water of the cistern is similarly pumped into tank *J*, and from here it is conducted to the apparatus of the ammonia factory.

The ammonia factory has two column apparatus *O*, system Gruenberg-Blum (other factories use the apparatus of Dr. Feldmann with equally good results) each of a capacity of 30,000 litres equal to thirty tons of ammonia water. The water enters at the top of the column, running from column to column downwards. Contrary to the course of the water flows dry steam, by which the ammonia is absorbed and forced along. The ammonia combined with water is dissolved by lime water. The lime water is pumped from lime box *Q* into the apparatus located above the stair column.

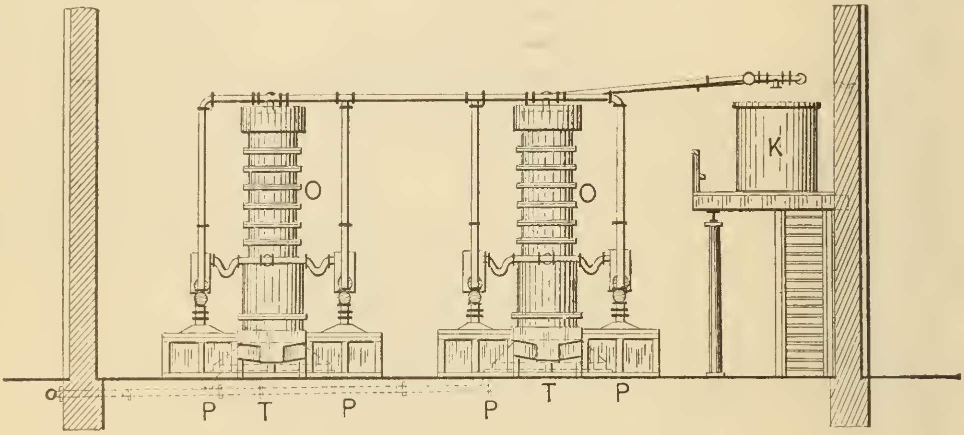

FIG. 8.—Section 3-4 of plan.

The steam saturated with ammonia is conducted either to the boxes *P*, lined with lead into sulphuric acid, and the ammonia and sulphuric acid combine to form sulphate of ammonia, or into coolers *K* to be condensed to concentrated ammonia water.

In order to obtain salt the ammonia fume is conducted to sulphuric acid and when the acid is saturated the salt is brought on the dripping platform *T*.

In order to obtain concentrated ammonia water, the product of condensation of coolers *K* is run into storage *U* of a capacity of about ten tons and thence by air pumps into railroad car tanks.

The sulphuric acid necessary for the manufacture of the salt is furnished by railroad car tanks and stored in tanks *V*, by means of air pumps and after its settlement it is conducted alternately from *V* and *V'* to tanks *P* by siphons and lead pipes.

The waters from apparatus *O* are conducted to a purifier, where the lime settles and the water runs off pure.

The Otto-Hoffmann ovens with coal distillation are most numerously introduced to-day, and there were in operation in Germany alone:

	Ovens in Operation	*Under Construction.*
1884,	40	120
1885,	120	140
1889,	605	
1891,	1,205	

The Otto-Hoffmann ovens are distributed as follows:

Coal District Westphalia,	470
Silesia,	705
Saar,	30
	1,205

The cost of such ovens is about 5,000 mks. per oven, and 7,000 mks. per oven for rest of the plant, or together 12,000 mks.; or a plant of sixty ovens would require an investment of about 720,000 mks. This cost seems exceedingly high, but the profits are so considerable that it may be ignored. Further, it must be regarded that all the important machinery, exhausters, ventilators, pumps are arranged in duplicate, by which the cost is increased considerably, and also that interruptions of operations are excluded, if a portion of the apparatus should become defective.

The quality of coke from the Otto-Hoffmann oven is a very good one and the gain is higher than from the same coal in common ovens. Formerly the gain from dry coal was about sixty-seven per cent. It is about seventy-five per cent. now, which is accounted for by the fact that the ovens with coal distillation always are closed air-tight, and therefore the combustion of the coal in the ovens cannot take place.

It can be assumed that one Otto-Hoffman oven produces 1,000 cubic metres of gas per day and consumes of these 600 cubic metres, leaving 400 cubic metres for other purposes.

A plant of sixty ovens in Westphalia furnishes a gas surplus of 24,000 cubic metres per day, by which boilers of 375 square metres heating surface can be heated. The condensation would require 140 to 150 square metres, leaving at disposal for other purposes about 230 square metres.

The following figures are from Upper Silesia: production per day 1,150 cubic metres; consumption per oven, 650 cubic metres; gas surplus per 60 ovens per day, 30,000 cubic metres.

Saar District and Westphalia: production per day, 1,000 cubic metres; consumption per oven, 600 cubic metres; gas surplus per 60 ovens per day, 24,000 cubic metres. One hundred cubic metres of gas are equal to 87·5 kilograms of coal, or 24,000 and 30,000 cubic metres of gas, respectively, equal to 21,000 and 26,250 kilograms of coal, respectively.

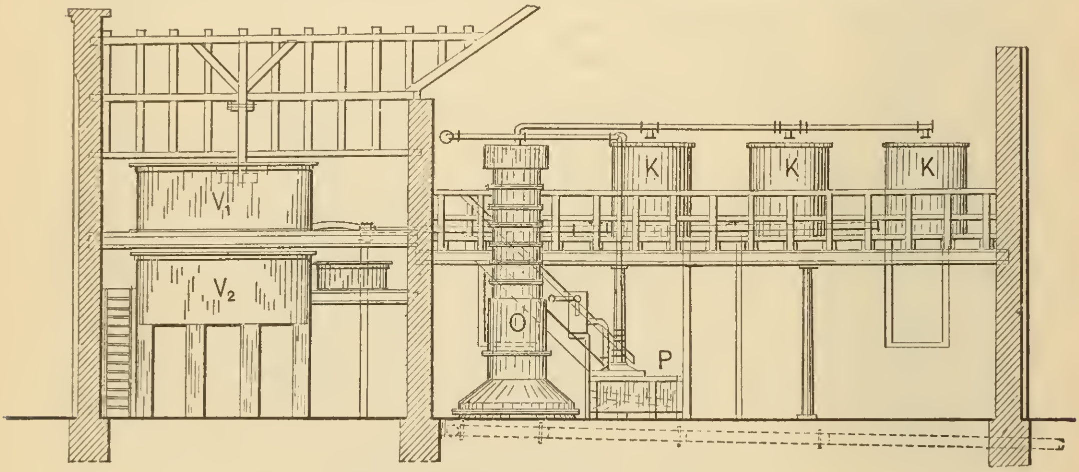

FIG. 9.—Section 1–2 of plan.

Instead of utilizing the surplus gas for heating boilers it might be used for illumination also, as is done at the Friedenshoffnung and Carl-George-Victor Mines at Gottesberg. A brief calculation of the results of a plant of sixty ovens in Westphalia is given in the following figures: 60 ovens with a distillation process of 48 hours = 30 ovens per day; per month 30 working days = 900 ovens per month. Each oven is charged with 7,100 kilograms of wet coal, containing about 12 per cent. of water, equal to 6,250 kilograms of dry coal.

Per month 900 × 6,250 = 5,625,000 kilograms of dry coal. According to experience, 100 kilograms of dry coal furnish on an average 1·15 kilograms of sulphate of ammonia = 64,687 kilograms per month and 2·75 kilograms tar = 154,687 kilograms per month.

	Mks.
100 kilograms of sulphate of ammonia are worth to-day 21·00 mks. = 64,687 × 21 . . . . =	13,584
100 kilograms are worth 3·50 mks. = 154,687 × 0·035 =	5,424
Receipts per month, ...	19,008

Total expenses:

Wages and other operating expenses, ...	5,700
Gross profits per month, ...	13,308
per annum	159,696

or 2,661 mks. per oven from the by-products only, against an investment of 12,000 mks. per oven or 7,000 mks. for the coal distillation; to which must be added the profits from the manufacture of coke. Interest and redemption are excluded in the calculation.

The results of the plants are more favorable in Upper Silesia, where the gain of sulphate of ammonia is as high as 1·25 per cent. and 4·5 per cent. of tar.

The results of the Saar District are not so favorable, especially in regard to ammonia.

I have mentioned already that the manufacture of benzole is still held as a secret, and I will remark only that the gain of benzole varies between 0·3 and 0·7 per cent. of the dry coal. On account of the fluctuating value of benzole I will give no estimate, as this might not be correct to-morrow. However, the course of the manufacture of benzole indicates that by and by also other products contained in the gas may be saved, and further developments of this industry are probable.

I must mention that besides the construction described a number of other systems are in operation with satisfactory results; for instance, the considerable plant of Appolt ovens at Florentine Mine, near Lagiewnik, which obtain remarkable results.

Machine Inspector Donders made the first experiments in 1883–84 to save the by-products without heating the air and without deterioration of the quality of coke, and his success led to the erection of the extensive plant referred to.

There were in operation 15,700 coke ovens in Germany in 1891, producing 7,700,000 tons of coke, of which about seventy per cent. was produced in the Ruhr District (Rhineland and Westphalia). The total number of these ovens could produce 110,000 tons of sulphate of ammonia and 275,000 tons of tar of a value of 32,000,000 mks. but only 18,000 tons of sulphate of ammonia and 45,000 tons of tar with a value of 5⅓ million mks. are produced by the manufacture of coke with coal distillation.

The figures of imports and exports of sulphate of ammonia (Chili nitrates and guano) from 1885 to May last show that the import of sulphate of ammonia since 1885 has not increased, but has decreased slightly, while the export is unimportant. But the import of Chili nitrates has increased enormously from 157,000 tons in 1885 to 396,000 tons in 1891, and to 235,000 tons within the first five months of this year.

	Mks.		*Mks.*
The value of imported sulphate of ammonia in 1891 is estimated per 100 kilograms, ...	24·00	=	7,466,000
Chili nitrates, per 100 kilograms, ...	17·50	=	69,239,000
Guano, per 100 kilograms, ...	15 80	=	7,865,000

against an export for the same period of :

	Mks.		*Mks.*
Sulphate of ammonia, per 100 kilograms, ...	24·00	=	230,000
Chili nitrates, per 100 kilograms, ...	18·50	=	1,831,000
Guano, per 100 kilograms, ...	16·00	=	444,000

Therefore, 84,065,000 mks. have been sent abroad for nitrates. Furthermore, these figures also show that by the reconstruction of all existing coke ovens of Germany to coal distillations, an overproduction would be excluded, for they could supply only twenty-five per cent. of the demand for nitrates, but 19,000,000 mks. would be saved to the country, and also an additional 8,000,000 mks. for tar.

Although we cannot expect that the total imports of nitrates can be supplied by sulphate of ammonia, the latest experiments of Professor Wagner at Darmstadt have demonstrated more favorable results, and he was enabled to declare before the last annual meeting of the gas and water experts that, while formerly he did not recommend the universal application of sulphate of ammonia for agricultural purposes, because manuring with Chili nitrates warranted results with more safety, he was now prepared to advise the farmers to its universal application, for he could state the conditions by which favorable results of different soils and plants could be obtained with safety.

It is not to be apprehended that with the application of sulphate of ammonia the increased production would be accompanied by reduced prices, for the value of nitrates is regulated by the world's markets.

.The development of the tar industry is a continuous one and its rapid extension is of much importance for coal mines, for it will supply them with pitch for the manufacture of briquettes from coal otherwise hardly marketable. According to *Glueck Auf* and the *Mine and Factory Gazette*, the consumption of pitch for the manufacture of briquettes is 150 tons per day, which would require 300 tons of tar, while the coke ovens in operation furnish about one-half of this, and the manufacture of briquettes certainly will be increased.

You will conclude from my address that the saving of by-products simultaneously with the manufacture of coke is of importance, not only for the coal and iron industry, but also of the highest importance from a politico-economic standpoint, and therefore its further development should be encouraged to the utmost.

REMARKS ON THE CHANGING OF THE PHYSICAL PROPERTIES OF COKE MADE IN THE BY-PRODUCT OVENS.

BY JAMES J. FRONHEISER.

The greatest fault found in Europe, and more particularly in England, with the coke made in the by-product ovens, was on account of its greater softness, in consequence of which, at the proper temperature, too much of it was wasted in the upper part of the blast furnace by being dissolved, as it were, by the escaping carbonic acid, thus: $CO_2 + C = CO$. (See *Journal of the Iron and Steel Institute*, of 1885, vol. i, p. 7.)

On p. 287 of Sir I. Lowthian Bell's *Manufacture of Iron and Steel*, we find the following:

"Hard coke, soft coke and charcoal pounded as near as possible to the same size were placed in a hard glass tube which they filled, and were then raised to a good, red heat in a Hofman's double furnace. During the space of thirty minutes, 800 cc. of carefully dried carbonic acid was passed over each specimen. The issuing gases had the following volumetric composition:

	Hard Coke.	*Soft Coke.*	*Charcoal.*
Carbonic acid,	94·56	69·81	35·2
Carbonic oxide,	5·44	30·19	64·8
	100·00	100·00	100 00"

Now, in order to correct the bad properties of soft coke, we recently tried some experiments with the same kinds of coal (Connellsville), coked it in a bee-hive oven under different conditions, and found by submitting the resulting coke to the same conditions used by Mr. Bell, the following results:

	Prepared Coke.	*Ordinary Coke.*	*Charcoal.*
Carbonic oxide,	8·72 cc.	43·76 cc.	217· cc.

Proving that under certain conditions the same coal can be treated so as to furnish harder coke than by the ordinary treatment, thereby overcoming the disadvantages charged to the coke made in the by-product ovens.

This process has recently been patented by C. S. Price, General Manager, and James J. Fronheiser, Superintendent of Laboratories of the Cambria Iron Company.

THE HELIOCHROMOSCOPE.

BY F. E. IVES.

[*Read at the stated meeting of the Institute, held Wednesday, Oct. 19, 1892.*]

Mr. JOS. M. WILSON, President, in the chair.

MR. IVES:—It was in 1888 that I first described and demonstrated, at the Franklin Institute, a method of reproducing the natural colors by photography, which differed in certain vitally important particulars from somewhat similar processes which had already been carried out by Cros and Du Hauron in Paris, Albert in Munich, Bierstadt in New York, and others. I succeeded in reproducing the natural colors in landscapes and various objects with a degree of accuracy which I have good reasons to believe had never before been approached by any method without the intervention of the artist's brush. The procedure was, however, too complicated and difficult for profitable commercial application, and comparatively few specimens were made.

I now present to your notice devices which so greatly simplify the operation of the process as to make it quite possible to place it in the hands of even the "press-the-button" class of amateur photographers, and yet yield results that are no more defective in color-rendering than the ordinary photograph is in the rendering of monochrome light and shade.

The first of these devices is a camera attachment, by means of which the three pictures representing the effect upon the three fundamental color sensations are made by a single exposure on a single sensitive plate, and from a single point of view. The device as now perfected is surprisingly simple, being comprised in a small box, which may be attached to the front board of an ordinary camera. The division of the light ray is effected by transparent mirrors, as in some of my earlier cameras, but in such manner as to dispose the images symmetrically on a single plane, without altering the position of the camera in relation to the object.

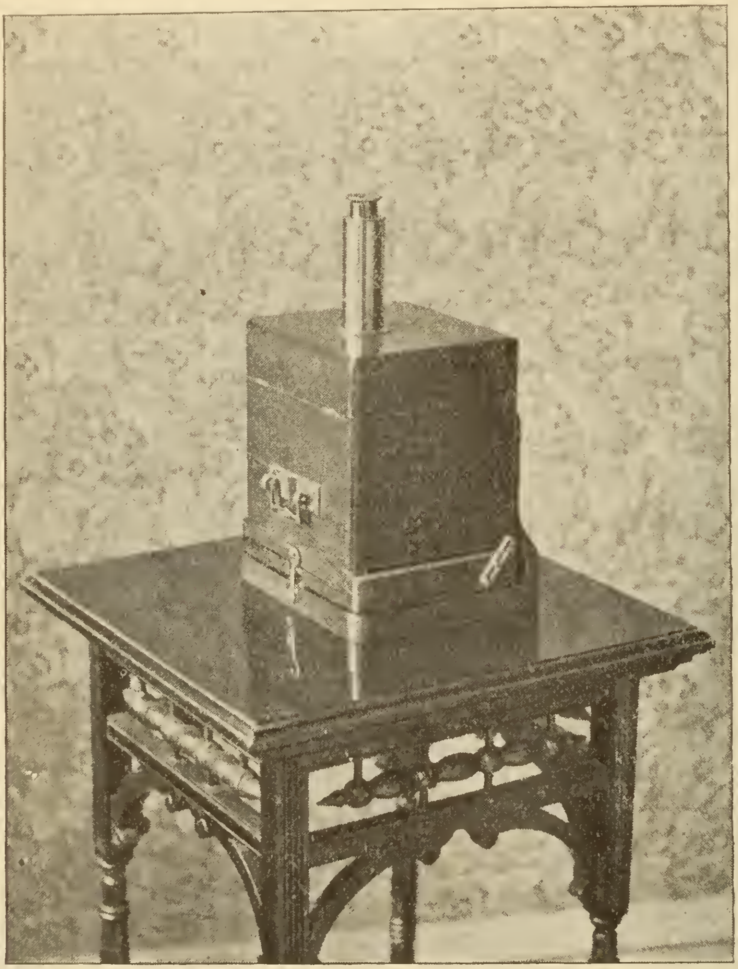

FIG. 1.—The Heliochromoscope.

The second device, which I call a heliochromoscope, contains the same arrangement of mirrors, turned about so as to serve to re-combine the three photographs in such manner that the photographic color record is translated into color again as readily as the sound record in the phonogram is translated into sound in the phonograph.

The most important advantage of this device is that it may be used at any time, at a minute's notice, like the stereoscope; and, as almost everybody may possess one, it is competent to make the realization of color photography a household affair. It also more completely fulfils the theoretical conditions of success than either the production of color prints or lantern projections, and produces an illusion of nature more correctly than would be possible with even an absolutely perfect color print on paper, because the picture is seen without surface reflections or distracting surroundings.

I claim for this system of color photography that it is perfectly rational and scientific, and a true solution of the problem of reproducing the natural colors in a photographic picture. This claim meets with a good deal of opposition in the minds of some people, whose mental attitude is a source of wonder to me, because the same sort of objections that are made to the triple photograph would apply to the stereogram and the phonogram. One is an automatic record of color, another of binocular vision, and another of sound; each must be placed in a special device in order to reproduce that which it has recorded—the triple photograph or chromogram into the heliochromoscope, the stereogram into the stereoscope, and the phonogram into the phonograph. I do not remember ever to have heard the stereogram denounced because it is not a single print with embossed relief, or the phonogram because it has no vocal cords.

Some even go so far as to deny that this can properly be termed color photography at all, although the same individuals are in the habit of calling pictures that cannot be made to show colors "orthochromatic" or correct-color photographs. But the most extreme illustration of this peculiar attitude of mind that I have seen is the assertion of one who, if I am not mistaken, has aspired to be the historian of photography, that this is merely "looking at ordinary photographs through bits of colored glass!" To be consistent, this writer should describe the stereogram as "two ordinary photographs, mounted on the same card," and the phonogram as a "wax cylinder having a roughened surface like an ordinary file." I believe he did recently write a history of photography, with "an introduction to its latest developments," without once mentioning color-sensitive plates.

I speak of this kind of criticism because it comes from men whose writings are in demand, and proves the existence of a deep-seated prejudice, which I have encountered in the development of other applications of photography, and which must be combated in order to overcome it. I will give an illustration: When, in 1880, I succeeded in realizing a mechanically accurate and practicable method

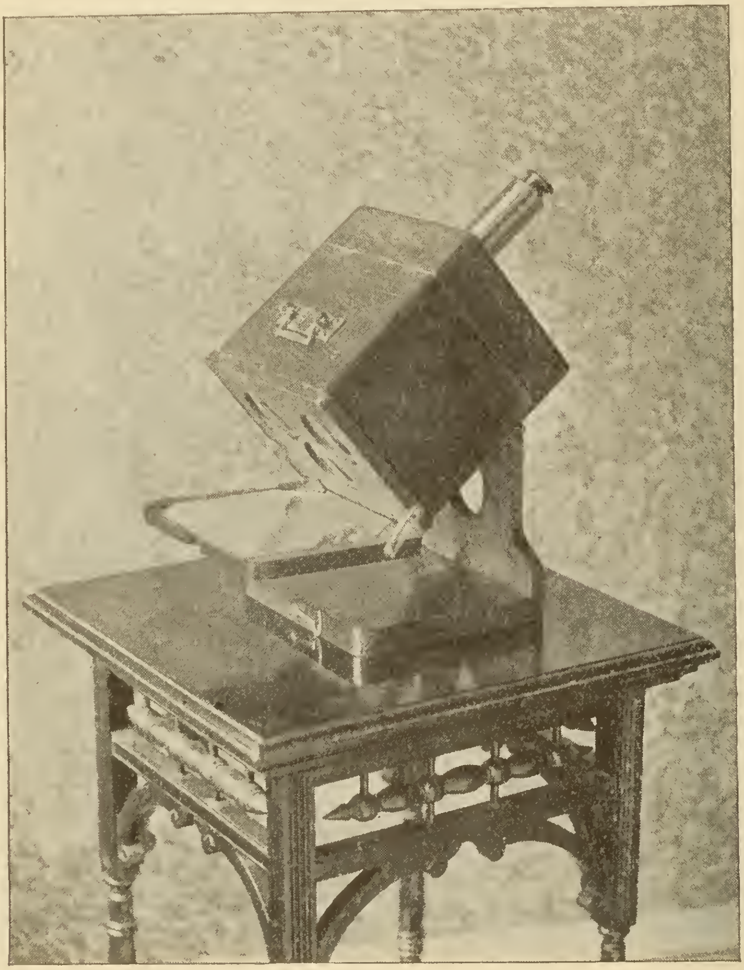

FIG. 2.—The Heliochromoscope.

of half-tone block-making, I could find only one engraver who believed there was a future for processes that rendered the shading in equally spaced graduated lines and cross-lines. Engravers, printers, publishers and photographers were agreed that if a block be made up of lines, those lines must follow the contours of the object depicted, as in the conventional wood engraving. Since that could not be done, a grain, similar to the well-known lithographic grain, must be substituted for the line tint. I declared that the objection to a regularly lined tint was a prejudice, stuck to it, and already, within twelve years, plates having that same lined tint have come into such extensive use as to replace millions of dollars' worth of wood engravings. They are used in illustrating books and periodicals of the highest class, and the advantages of the mechanical-lined tint are such that it threatens even to invade the domain of photogravure. Mr. Louis E. Levy exhibited such results at the last monthly meeting of the Franklin Institute, and I myself applied for a patent on a printing plate of this character more than a year ago, having first experimentally demonstrated certain important advantages which they can be made to possess.

We did not make half-tone printing plates of the kind that engravers and printers and publishers thought they must have, but they have concluded to take what we did make, and are taking them more and more every year.

We have not made photographs in the natural colors of exactly the kind that people have been looking for, and there is good reason to doubt if such a result will ever be accomplished by a simple process; but we have actually realized, by a process almost as simple as stereoscopic photography, results better than can even be hoped for in color prints, and so perfect that they must ever represent the standard which results by any other method must be made to approach in order to be acceptable. A great many people seem to think that this is not what they want; but I have quite as much faith in the future of the heliochromoscope as I ever had in the future of half-tone block-making in line. It has been a revelation to me, and I believe it will be to the whole world.

I met a professional artist in London, a clever painter of both portraits and landscapes, who spent what seemed to me a very long time studying a bouquet of English flowers reproduced in the heliochromoscope, and left it only to return to it again and again, as if it fascinated him. At last a friend asked him for an expression of opinion upon the merits of the device. After some hesitation, he said that he had attended one of my lectures at the Royal Institution, expecting to go away and report the failure of another attempt to reproduce the natural colors by photography. He had not been able to do so, but was forced to confess that color photography is a fact. The demonstration was conclusive to him. The heliochromoscope will have no better friends than the artists, for whom it will not only reproduce nature, but the masterpieces of art as well, in such manner that they can be studied in far-distant lands almost as well as in the galleries where they repose.

In the far West, I met the representative of a large New York firm of importers of Oriental rugs. He assured me that he was ready to pay $100 out of his own pocket for a duplicate of the heliochromoscope that I showed him, with a set of photographs of the rugs that he carried about with him only to show their colors. It would save his firm a great deal of money that went in expensive sample rugs, and in cost of extra baggage, and it would save him a great deal of trouble. A professional house decorator spoke much to the same effect. Evidently, the heliochromoscope will have many fields of usefulness—so many, perhaps, that its function as a source of drawing-room entertainment, for which alone many have supposed it to be adapted, will prove of secondary importance. But I shall be greatly surprised if, even for the latter purpose, it does not become more popular than the stereoscope ever was, although it is necessarily a much more expensive instrument

I have said that this system of photography is capable of giving reproductions that are no more defective in color rendering than the ordinary photographic process is in the rendering of monochrome light and shade. Not to be misunderstood, let me say that no photographic process is capable of reproducing even monochrome light and shade with strict accuracy. The most correct negative-making process will exaggerate contrasts in the middle shades of the picture at the expense of the two ends of the scale. The same defect necessarily appears in the color process, making colors too pale in the light shades and too dull in the dark shades, with slight exaggeration of contrasts in the middle shades. This defect would not generally be noticed by most persons, and it would not be fair or reasonable to count it against this process any more than it is counted against ordinary photography.

The most serious practical difficulty encountered in the operation of the process is due to unevenness, often slight, in the coating of the sensitive plates. Unevenness that would not be noticed in ordinary negative work often seriously affects the result in this process. This difficulty can be readily overcome by the plate-makers; but it will not pay them to make the necessary changes until there is a considerable demand for plates for this work, and then they will be obliged to charge more for them than they now do for the ordinary plates. With such sensitive plates as I would ask for, and know that it is quite possible for the plate-makers to provide, the average results by this process should be better than the best that I have shown.

The subject now in the heliochromoscope is a bouquet of Yellowstone Park wild flowers, gathered by Mr. Jennings. We placed it in a pitcher borrowed from the dining-room of the Lake Hotel and photographed it in our bed-room. You will see the bouquet as it would appear by gaslight, because I am using gaslight as a source of illumination. By daylight, the colors are exactly as they appeared to us when we photographed it.

HAINES AUTOMATIC MICROMETER GAUGE, FOR GAUGING EITHER HOT OR COLD ROLLING MILL WORK TO EXACT THICKNESS WHILE IN THE ACT OF ROLLING.

By R. B. Haines, Jr.

[*Read at the stated meeting of the Institute, November 16, 1892.*]

Mr. Jos. M. Wilson, President, in the chair.

Mr. Haines:—The automatic micrometer gauge was designed to meet the demand for more accuracy in rolling sheet, bar or plate metal to exact thickness than has heretofore been obtained by the ordinary fixed or caliper gauges. It was specially designed for gauging hot work while in the act of rolling, so that the roller might know, at each pass of the metal through the rolls, the exact amount of reduction and what adjustment are necessary for the succeeding pass and finally to finish the work to the proper thickness. In rolling such material as boiler-, ship- or tank-plate, this is particularly important. The rolls cannot be set as in a rail mill, where large quantities of duplicate pieces are turned out, but must be adjusted constantly for each plate rolled. One plate is to be finished three-eighths of an inch thick, the next one-fourth of an inch, the following 1·13 inches, the next one-half inch, and so on. This applies as well where a large number of plates of the same thickness are required, as the rolls must be opened wide enough to receive the bloom or ingot, then are gradually closed together while the bloom is passed backward and forward between them till the desired thickness is reached. In modern mills there is an indicating attachment connected with the large housing screws (for closing the rolls together), that will show how much the bloom is being reduced by each pass, and will give an approximate idea when the plate is reduced to the proper point, but it can never be relied on to determine the exact amount required for the finishing pass, as it will not measure the compression of the screws and bearings, the springing of the rolls, or make allowance for the extra diameter caused by heating. Hand gauges must, therefore, be used to make this determination. The instrument in common use is the fixed or caliper gauge, and just herein lies the difficulty in getting accurate work. Take, for instance, the plates for a marine boiler. These are usually of large size, a single one often weighing 6,000, 8,000 or 10,000 pounds, and gauging (say) seven-eighths, one and one-thirty-second or one and one-half inches. They are calculated by the engine designers to a certain thickness, in order to carry a suitable pressure for the engines. Should they fall below this thickness, the safe working pressure is cut down for every one-hundredth of an inch under the gauge; if the plates should be over the calculated thickness, the purchasers object to the excess of weight. In either case allowances must be made, or the material is rejected, both of which are undesirable. In making these plates suppose a common fixed caliper gauge is used. The roller, judging by experience when the plate is nearly down to thickness, tries the gauge on it. One of three things happens: either the gauge will not go on the plate, or it will go on just right, or else will go on too loosely. If it goes on too loosely the mischief is done. If it fits just right the point is gained, but when the gauge will not go on the plate, there is yet a chance to make it right or spoil it. To make it right another pass is necessary and a definite knowledge of the amount of reduction required is of vital importance. With the fixed gauge this is mere conjecture. It may take two or three passes of very slight reduction each, but that takes time and there is still a risk of going too far, whereas, if the exact amount were known, one pass would have sufficed. The need to determine definitely this unknown quantity led to the invention of the automatic micrometer gauge. Heretofore it was hardly necessary to work to such close measurements, but the tendency of the present time along all lines is toward greater accuracy, and what would have passed, a short time ago, is rejected to-day. The automatic micrometer gauge is somewhat similar in general character to a micrometer caliper, but the construction is different, as the conditions of use are not at all similar. The gauging screw is made with coarse pitch and double thread, and has for a head a graduated disc about two and one-half inches in diameter, which indicates the measurements. The edge of this disc is serrated and can be clamped or held at any point, to prevent turning, by a locking bar or knife edge arranged to slide in between the teeth at the will of the operator. The movement of this locking bar is controlled by a trigger (on the gauge handle), operated by the forefinger. The handle is made of sufficient length to enable the person using it to measure hot work with ease. Fastened to the gauging screw, directly under the disc, is a spiral spring which tends to rotate the disc, and thus close the screw upon any article to be measured. In practical working, for instance in gauging a hot plate, the dial is turned by hand (to open the gauge screw) considerably more than the finished thickness of the plate; the gauge is then put on the plate and the trigger pulled. The spiral spring causes the disc to revolve and sets the gauge screw on the surface of the plate. The trigger is now released and the locking bar engaging the teeth of the disc prevents it from turning while the gauge is pulled off the plate to take the reading. The graduations on the face of the disc indicate the thickness. This can be repeated at each pass through the rolls and will show the amount of each reduction. In following the work down in this manner, the exact amount of reduction for the finishing pass will be determined. The whole operation is extremely simple, yet gives the gauger at all times, definite measurements that show at each step just what is being done. The gauge weighs about two and one-fourth pounds. It is operated altogether with one hand, excepting when set for the first time for each plate.

A single one replaces all the fixed caliper gauges for standard thickness (within its range), and obviates entirely the expense of making special gauges for special thicknesses. In our own work we seldom roll plates less than three-sixteenths of an inch thick, and between that and one and one-half inches which is about the heaviest. We formerly used thirty-three caliper gauges, besides frequently making special tools for odd sizes.

These we have now discarded and use in place of them three of the automatic micrometer gauges.

We have had them in use for several months and the result shown in the increased accuracy of the work is very satisfactory.

MAXIMUM STRESSES FROM MOVING SINGLE LOADS IN THE MEMBERS OF THREE-HINGED ARCHES.

By Emrick A. Werner.

[*Continued from vol. cxxxiv, p. 448.*]

II

Suspension Bridge with Parabolic Line of Thrust and Triangular Stiffening Truss.

x	y	f	$\frac{y}{f}$	$\tan\mu$	$\cos\mu$	
15	10·8	30·0	0·36	$\frac{10\cdot8}{15} = 0\cdot72$	0·811	$\tan\mu_6 = \frac{30}{33} = 1\cdot10$
30	19·2		0.64	$\frac{8\cdot4}{15} = 0\cdot56$	0·872	$\cos\mu_6 = 0\cdot671$
45	25·2		0·84	$\frac{6\cdot0}{15} = 0\cdot40$	0·928	$\tan\alpha = \frac{17\cdot5}{15} = 1\cdot17$
60	28·8		0·96	$\frac{3\cdot6}{15} = 0\cdot24$	0·972	$\cos\alpha = 0\cdot651$
75	30·0		1·00	$\frac{1\cdot2}{15} = 0\cdot08$	0·996	

$$\tan\mu_{m+1} - \tan\mu_m = 0\cdot16$$

$$h = 17\cdot5$$

One hundred and fifty foot span, ten panels, fifty feet each thirty-foot rise.

The thrust is taken up fully by the cable, which has thus the form of the line of thrust. As stiffening truss is used a triangular truss of 17·5 depth. The dead load is assumed to 26,000 pounds per panel point — 14,000 pounds acting at the bottom chord, 4,000 pounds at the top chord and 8,000 pounds at the cable.

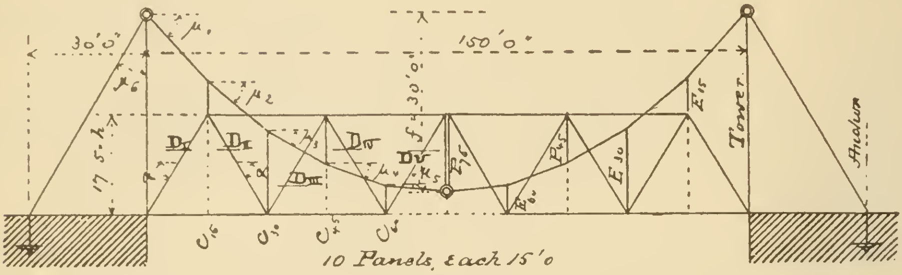

FIG. 31.

The moving load are the two engines, followed by 3,000 pounds per foot of the track, shown in *Fig. 1*.

The above diagram gives all the data of calculation.

Horizontal Stress in the Cable.—Line of thrust, loading, span and rise being the same as in example *I*, the reactions will be the same as in the upright arch.

$$Max.\ H = 378{,}500$$

$$Min.\ H = 0$$

Vertical stress in the suspension rods E.

$$E\ max. = H\ max. (tan\ \mu_{x+\Delta x} - tan\ \mu_x) = 0{\cdot}16 \times 378{,}500 =$$

$$= 60{,}600 \text{ pounds.}$$

$$E\ min. = 0$$

$(Tan\ \mu_{x+\Delta x} - tan\ \mu_x)$ is constant in the parabola, hence the vertical stress is the same in all rods.

Horizontal stress in the chords.

As no thrust is taken up by the chords, both chords have the same general equation as the upper chord of the upright arch, and

$$\left(\frac{M}{h}\right)$$

reaches its maximum and minimum, as shown there.

Maxima (moments positive):

$$C_{15} = \left(\frac{M}{h}\right)_{15} = 79{,}300$$

$$D_{\text{I}} = +\ 79{,}300$$

$$C_{30} = \left(\frac{M}{h}\right)_{30} = 108{,}200$$

$$D_{\text{II}} = +\ 36{,}400$$

$$C_{45} = \left(\frac{M}{h}\right)_{45} = 103{,}900$$

$$D_{\text{III}} = +\ 45{,}000$$

$$C_{60} = \left(\frac{M}{h}\right)_{60} = 62{,}600$$

$$D_{\text{IV}} = -\ 30{,}200$$

Minima (moments negative):

$$C_{15} = \left(\frac{M}{h}\right)_{15} = -\ 71{,}500$$

$$D_{\text{I}} = -\ 71{,}500$$

$$C_{30} = \left(\frac{M}{h}\right)_{30} = -\ 104{,}000$$

$$D_{\text{II}} = -\ 32{,}500$$

$$C_{45} = \left(\frac{M}{h}\right)_{45} = -\ 99{,}700$$

$$D_{\text{III}} = +\ 3{,}300$$

$$C_{60} = \left(\frac{M}{h}\right)_{60} = -62{,}100$$

$$D_{\text{IV}} = +\ 35{,}200$$

Horizontal stresses D in the diagonals.

As the depth h of the stiffening truss is constant, these values will be different from those of the upright arch.

$$D_{\text{I}} = \left(\frac{M}{h}\right)_{15} - \left(\frac{M}{h}\right)_{0} = \left(\frac{M}{h}\right)_{15} = [0{\cdot}72\ W_1 g_1 +$$

$$+\ W_2 (15 - 0{\cdot}28\ g_2) - 0{\cdot}08\ W_3 g_3] \frac{1}{17{\cdot}5}$$

$$D_{II} = \left(\frac{M}{h}\right)_{30} - \left(\frac{M}{h}\right)_{15}$$

$$\left(\frac{M}{h}\right)_{30} = [0{\cdot}48\ W_1 g_1 + W_2 (30 - 0{\cdot}52 g_2) - 0{\cdot}12\ W_3 g_3] \frac{1}{17{\cdot}5}$$

$$\left(\frac{M}{h}\right)_{15} = [0{\cdot}72\ W_1 g_1 + W_2 (15 - 0{\cdot}28 g_2) - 0{\cdot}08\ W_3 g_3] \frac{1}{17{\cdot}5}$$

$$D_{II} = [-0{\cdot}24\ W_1 g_1 + W_2 (15 - 0{\cdot}24 g_2) - 0{\cdot}04\ W_3 g_3] \frac{1}{17{\cdot}5}$$

$$D_{III} = \left(\frac{M}{h}\right)_{45} - \left(\frac{M}{h}\right)_{30} = [-0{\cdot}20\ W_1 g_1 + W_2 (15 - 0{\cdot}20 g_2)] \frac{1}{17{\cdot}5}$$

$$D_{IV} = \left(\frac{M}{h}\right)_{60} - \left(\frac{M}{h}\right)_{45} = [-0{\cdot}16\ W_1 g_1 + W_2 (15 - 0{\cdot}16 g_2) + 0{\cdot}04\ W_3 g_3] \frac{1}{17{\cdot}5}$$

$$D_V = \left(\frac{M}{h}\right)_{75} - \left(\frac{M}{h}\right)_{60} = -\left(\frac{M}{h}\right)_{60}$$

Maxima.—

$$D_I\ max. = \left(\frac{M}{h}\right)_{15} max. = 79{,}300$$

D_{II} *max.*

Maximum line $g_m = \frac{1{,}500}{24} = 62{\cdot}5$

Max. span = space from (30) to (62·5)

a and c being negative.

$$\frac{dD}{dg} = -a(w) + \beta W_2 + \frac{w}{\Delta x}[a x - (k - \beta x)]$$

$$= +0{\cdot}24\ w + 0{\cdot}24\ W_2 - w$$

introducing

$$w + W_2 = W = \text{total load.}$$

$$\frac{dC}{dg} = 0{\cdot}24\ W - w$$

First wheel 17·75 from Abutment *A*, last tender wheel 85·25 from Abutment *B*.

$$D_{\text{II}} = \left(\frac{M}{h}\right)_{30} - \left(\frac{M}{h}\right)_{15} = (1{,}553 - 738)\,\frac{1}{17{\cdot}5} = 46{,}600 \text{ pounds.}$$

D_{III} *max.*

$$\text{Max. line} = \frac{1{,}500}{20} = 75$$

Max. span = space from (45) to (75)

a and *c* being negative.

$$\frac{d\,D}{d\,g} = +\,0{\cdot}20\;W - w$$

First wheel 37·0 from Abutment *A*, last tender wheel 66·0 from Abutment *B*.

$$D_{\text{III}}\ max. = \left(\frac{M}{h}\right)_{45} - \left(\frac{M}{h}\right)_{30} = [370 - (187)] \div 17{\cdot}5 =$$

$$= +\;31{,}800$$

Note.—The general equation of D_{III} having no member $W_3\,g_3$, the absolute value of D_{III} is independent of any load on W_3.

Check.—The same loading as above, with the addition of the second engine in W_3.

$$D_{\text{III}} = \left(\frac{M}{h}\right)_{45} - \left(\frac{M}{h}\right)_{30} = [-\,558 - (-\,1{,}115)] \div 17{\cdot}5 =$$

$$= +\;31{,}800$$

D_{IV} *max.*

$$\text{Max. line } g_{\text{m}} = \frac{1{,}500}{16} = 93{\cdot}75$$

Max. span = space from (60) to end of truss.

a being negative.

$$\frac{d\,D}{d\,g} = 0{\cdot}16\,w + 0{\cdot}16\,W_2 + 0{\cdot}04\,W_3 - w$$

or

$$w + W_2 = W_{\text{I}}$$

$$= [0{\cdot}16\,W_{\text{I}} - w] + 0{\cdot}04\,W_3$$

First wheel 52·0 from Abutment A, third wheel of second tender 1·5 from Abutment B.

W_I and w change, the dividing line being in (60).

$$D_{IV}\ max. = \left(\frac{M}{h}\right)_{60} - \left(\frac{M}{h}\right)_{45} = [-627 - (-1{,}485)] \div$$

$$\div\ 17·5 = 49{,}000$$

$$D_{V}\ max. = -\left(\frac{M}{h}\right)_{60} = -62{,}600$$

Minima.—

$$D_{I} = \left(\frac{M}{h}\right)_{15}\ min. = -71{,}500$$

D_{II} *min.*

Maximum line $g_m = 62·5$

Minimum span = spaces corresponding to negative a, c and $\left(\frac{l}{2} - g_m\right)$ = space from (o) to (45) and from (62·5) to end (150).

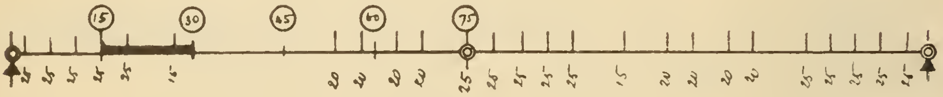

FIG. 32.

$$\frac{dD}{dg} = -a(W_1 + w) + \beta W_2 + c W_3 + \frac{w}{\Delta x} \times$$

$$\times [a x - (k - \beta x)]$$

introducing

$$W_1 + w + W_2 = W_I$$

$$= [0·24\ W_I - 0·04\ W_3] - w$$

W_1 and W_3 change, as dividing line = top hinge.

Note.—$W_1 g_1$ must be a maximum, hence a load in (15).

$$D_{II} = \left(\frac{M}{h}\right)_{30} - \left(\frac{M}{h}\right)_{15} = [-900 - (-268)] = 17·5 =$$

$$= -36{,}100 \text{ pounds.}$$

[*To be continued.*]

PROCEEDINGS

OF THE

CHEMICAL SECTION

OF THE

FRANKLIN INSTITUTE.

[*Stated meeting held Tuesday, December 20, 1892.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, December 20, 1892.

Dr. Wm. H. Wahl, President, in the chair.

The special business of the evening being the election of officers for the coming year, this matter was considered first.

Letters from the various candidates were read, accepting or declining their nominations made at the November meeting. The gentlemen accepting nominations were Dr. Wm. H. Greene for President, Mr. Henry Bower and Dr. D. K. Tuttle for Vice-Presidents, two to be elected.

The nominees for the remaining offices were the present incumbents, Wm. C. Day, Secretary; Dr. H. W. Jayne, Treasurer, and Dr. Wm. H. Wahl, Conservator.

The Secretary was directed to cast the vote of the Section for all the candidates above-named.

Mr. H. Pemberton, Jr., nominated Mr. Geo. P. Tucker, of the Patent Office, Washington, D. C., and Dr. Wahl nominated Mr. W. J. Williams, of Wilmington, Del.

The Committee on Admission having considered the candidates presented, declared them elected members of the Section.

The annual report of the Treasurer was read and referred to the Auditing Committee, who examined the accounts, and the report was accepted.

The Secretary's annual report was read and accepted.

The committee in charge of the reception tendered, on the 5th inst., to Dr. H. W. Wiley, of Washington, D. C., made a report, which was accepted with a vote of thanks and the committee was discharged.

The Secretary suggested that the interest of our meetings might be increased if during the year we could secure a limited number of papers, giving in condensed form an account of the development of certain subjects either of technical or purely scientific import, thereby showing the present state of knowledge of those subjects. At the suggestion of Dr. Jayne, the matter was referred to a committee to be named by the Chair to consider the advisability of the suggestion and to formulate a plan for carrying it out. The President appointed Dr. Wm. H. Greene, Mr. H. Pemberton, Jr., and the Secretary members of this committee, with instructions to report at the January meeting.

Dr. S. C. Hooker read a paper on "Di-brom β-Lapachone: its Preparation and Properties." The paper was the joint production of Dr. Hooker and Mr. A. D. Gray.

Dr. Hooker read also an abstract from the "Annual Report of the Secretary of Internal Affairs of Pennsylvania, Department of Industrial Statistics." This abstract treated of the progress of the process of sugar refining as at present conducted at the Franklin Sugar Refinery of Philadelphia. The article showed clearly and in detail the high state of perfection to which the sugar refining industry has been brought.

Both papers called forth considerable discussion from the members present.

Specimens of the substances discussed in both papers were presented for inspection.

A paper on "Artesian Wells as a Water Supply for Philadelphia," by Prof. O. C. S. Carter, of the Central High School of Philadelphia, was submitted by Dr. Greene; it was read by title and referred for publication.

The Section then adjourned. WM. C. DAY, *Secretary.*

THE DEPOSITS OF NATIVE SODA, NEAR LARAMIE WYOMING.

BY H. PEMBERTON, JR., AND GEO. P. TUCKER.

[*Read at the stated meeting of the Chemical Section, November 15, 1892.*]

Previous to the Civil War, and at a time when the line of civilization extended as far only as the Mississippi River, very little was known of the part of the United States west of that limit. A vast region now comprising many large States was described in the geographies of the day as "the great American Desert." It constituted a part of the prairies or plains, so often mentioned in Cooper's novels. And while the prairies, as a general rule (and particularly in elevations not much above sea-level), are composed of a fertile and rich soil, their character changes as the approach is made to the Rocky Mountains, and when an elevation of 7,000 feet is reached as in Wyoming, the soil and climate resemble somewhat the soil and climate of Nevada and other parts of the Great Basin. On this high Wyoming plateau, particularly in the neighborhood of the town of Laramie, one drives for miles over a perfectly flat country, with nothing but some distant hills to break the wide circle of the horizon—not even a single tree. A little thin grass grows in the gravelly soil, but no other form of vegetation, except when aided by irrigation. The region is nearly rainless, the relative humidity quite low, and all conditions favorable to the formation of the saline deposits peculiar to this portion of the United States.

About fourteen miles southwest of Laramie, there exists a deposit of sulphate of soda, such deposits are locally known as "lakes." The deposit in question is composed of three of these lakes lying within a stone's throw of one another. They have a total area of about sixty-five acres, the local names of the three being the Big Lake, the Track Lake and the Red Lake. They are the property of the Union Pacific Railroad Company, are connected by a branch of that road with the main line at Laramie, and are generally known as the Union Pacific Lakes.

In these lakes the sulphate of soda occurs in two bodies or layers. The lower part constituting the great bulk of the deposit, is a mass of crystals of a faint greenish color, mixed with a considerable amount of black slimy mud. It is known as the "solid soda." We give an analysis of this below.

ANALYSIS OF SOLID SODA IMMEDIATELY UNDER THE TOP LAYER OF WHITE SULPHATE OF SODA ON RED LAKE AND TRACK LAKE (U. P. LAKES).

	Anhydrous. Per Cent.	*Crystallized. Per Cent.*
Na_2SO_4,	36·00	81·63
$CaSO_4$,	1·45	1·82
$MgCl_2$,	·77	1·64
NaCl,	·21	·21
	38·43	85·30
Insoluble residue (at 100° C.),		13·86
		99·16

Total chloride calculated as NaCl equals 1·16 per cent.

This calculated on 100 parts anhydrous: Na_2SO_4 equals 3·22 per cent. NaCl.

This solid soda is stated to have a depth of some twenty or thirty feet. Borings were made a number of years ago under the direction of the Union Pacific Railroad agents, but all attempts to obtain the results of the same were futile, as the records have been mislaid or lost. There is nothing to prove that the depth is not shallower than stated above.

Above the solid soda occurs the superficial layer of *pure white crystallized sulphate of soda.* This is formed by solution in water of the upper part of the lower body—the crystals being deposited by evaporation or by cooling, or by the two combined. A little rain in the spring and autumn furnishes this water, as do also innumerable small, sluggishly flowing springs present in all the lakes. But on account of the dry air of this arid region, the surface is generally dry or nearly so, and in midsummer the white clouds of efflorescent sulphate that are whirled up by the everblowing winds of Wyoming can be seen for miles. Even should there be a little water present, there is no difficulty in gathering the crystals by the train load. The spring, however, is the worst season of the year, on account of the warm weather and of the rains—conditions unfavorable to the formation of crystals. The layer of this white sulphate is from three to twelve inches in thickness. When the crystals are removed, the part laid bare is soon replenished by a new crop.

The following is an analysis of the purest of this white sulphate of soda, calculated upon an anhydrous basis; that being the condition, of course, in which it would be used.

Na_2SO_4,	99·73
$MgCl_2$,	·26
Insoluble,	trace
	99 99

Several hundred tons of this have been shipped by the railroad to the works at Laramie City. The plant there for dehydrating the crystals is not of the best, and the long exposure to the dust and smoke of the fire gases in the evaporation—and again in the calcining—introduces more or less impurity into the finished calcined sulphate of soda. The following is an analysis of the latter:

	Finished Calcined Sulphate of Soda. (From U. P. Lakes.)	
Na_2SO_4,	95·80	soluble in water.
$CaSO_4$,	·76	
NaCl,	1·84	
Ignition,	·19	insoluble in water.
SiO_2,	1·48	
Fe_2O_3,	·06	
Al_2O_3,	·31	
CaO,	·20	
MgO,	·44	
	101·08	

This analysis represents the general run of the sulphate, as manufactured in Laramie. The sample was taken from a carload lot sold to the Wyoming Glass Company. It contains only a trace of iron, and, of course, no free acid.

At the time when we examined these lakes, in 1888, they were entirely under water. An irrigating canal—or "ditch"—had been located within a half mile of them, the water from which had gradually collected to the extent of several feet in the lakes. The course of the canal has since been changed, and the lakes are again in about their normal condition.

Samples of this water were collected by us, and analyzed as giving a very fair idea of the average composition of the deposits. The ingredients are calculated to the anhydrous condition. The last item, it will be noticed, is given as anhydrous borax, $Na_2B_4O_7$. It represents the results of titration with standard acid, using methyl orange as an indicator. It may be noted that, on account of the lime salts present in solution, alkaline carbonates and phosphates must be absent, and direct test proved the absence of soluble silicates. We have noticed the same titration reaction (if we may so call it) in a sample of sulphate of soda from a deposit near Rawlins, Wyoming, and, in general, it may be stated that the character of the climate, soil, and formation in Wyoming is very similar to that of such parts of the Pacific Slope as are known to contain deposits of borax.

WATER FROM BIG LAKE (U. P. LAKES).

Density = 9¾° Tw. (= 1·0487 sp. gr.)

10 cc. contains:

	Grams.		Per Cent.
Na_2SO_4,	0·4490	=	81·43
$CaSO_4$,	0·0175	=	3·17
$MgSO_4$,	0·0060	=	1·09
$MgCl_2$,	0·0643	=	11·66
$Na_2B_4O_7$?	0·0146	=	2·65
Total solids,	0·5514		100·00
(Total solids by evaporation,	0·5417)		

One cubic foot contains $6\frac{36}{100}$ pounds of pure crystallized sulphate of soda.

WATER FROM TRACK LAKE (U. P. LAKES).

Density = 14½° Tw. (= 1·0725 sp. gr.)

10 cc. contains:

	Grams.		Per Cent.
Na_2SO_4,	0·7563	=	92·23
$CaSO_4$,	0·0146	=	1·79
$MgSO_4$,	0·0070	=	·85
$MgCl_2$,	0·0300	=	3·66
$Na_2B_4O_7$?	0·0121	=	1·47
Total solids,	0·8200		100·00
Total solids by evaporation,	0·8240		

One cubic foot of this water contains $10\frac{72}{100}$ pounds of pure crystallized sulphate of soda.

WATER FROM RED LAKE (U. P. LAKES).

Density = 17¾° Tw. (= 1·0887 sp. gr.)

10 cc. contains:

	Grams.		Per Cent.
Na_2SO_4,	0·9307	=	91·77
$CaSO_4$,	0·0201	=	1·98
$MgSO_4$.	0·0143	=	1·41
$MgCl_2$,	0·0416	=	4·10
$Na_2B_4O_7$?	0·0075	=	·74
Total solids,	1·0142		100·00
Total solids by evaporation,	1·0320		

One cubic foot of this water contains $13\frac{19}{100}$ pounds of pure crystallized sulphate of soda.

We give, also, below analysis of sulphate of soda from lakes controlled by Col. S. W. Downey, of Laramie. Of these deposits we know but little other than that they are situated about twenty-five miles southwest of Laramie, and as indicated by the analyses, are contaminated by lime and magnesia salts to a considerable degree. Both analyses were made on samples previously calcined.

	S. W. Downey's Wilcox Lake.	*S. W. Downey's Red Soda.*
Na_2SO_4,	43·12	69·55
$MgSO_4$,	41·70	6·75
$CaSO_4$,	—	11·24
NaCl,	·20	1·01
Ignition,	·32	·33
Insoluble,	16·15	10·50
	101·49	99·38

From a commercial standpoint these Wyoming deposits are interesting, inasmuch as they furnish cheaply and in large quantities quite a pure grade of sulphate of soda. This sulphate being free from iron, and also, of course, from free acid, is well adapted to use in the manufacture of glass. Freight rates from the East are in its favor and allow a price that should yield a fair profit. Attempts have been made at Laramie on quite an elaborate scale, to manufacture soda ash and caustic by the Leblanc process. These efforts were not remunerative.

ARTESIAN WELLS AS A WATER SUPPLY FOR PHILADELPHIA.

By Oscar C. S. Carter,
Prof. Geology and Mineralogy, Central High School, Philadelphia.

[*Read by title, December 20, 1892.*]

The long-continued drought of the summer of 1892 was unusually severe, the rise of even a couple of inches was eagerly noted in the city reservoirs and frequent warnings were given to use no more water than was absolutely necessary. The frequent low-water mark of the Schuylkill and its well-known impure condition in dry seasons are strong reasons for causing us to seek a new supply of pure and wholesome water. Even if artesian wells will not entirely take the place of the Schuylkill they will at least prove a powerful aid, both in quality and quantity. After keeping a complete record of more than twenty wells that have been drilled recently in Montgomery, Philadelphia, Chester and Delaware Counties I would strongly urge a trial of artesian water. The two main points to consider are the purity and the quantity. First, as regards purity, it is a well-known fact that water which has filtered through from 200 to 500 feet of rocky strata is practically free from organic and all deleterious matter. It is never muddy or dirty but always clear and free from sediment. The wells are cased or lined with iron pipe sometimes to a depth of 100 feet. This effectually shuts off any surface drainage, so that it would be impossible for disease germs which are common in river water to reach these deep wells. As a rule artesian water is pure, sparkling and wholesome. It sometimes happens when a well is newly drilled that the water may have a slight mineral taste, due to the salts of lime, magnesia, potash and iron dissolved by being in contact with the rocks for a long time, or it may be a trifle hard. This, however, from experience, we know, is rarely the case, and it soon disappears when the water has been pumped for a certain time because new water filters in and takes its place. One instance in particular may be given in this city where the water was used for boilers and became quite soft on continuous pumping. The water of nearly all the wells drilled in this vicinity is in constant use for drinking water and has proved satisfactory.

It will be urged by many, no doubt, that the supply derived from artesian wells is insignificant and, as a rule, that it is difficult to find water-bearing strata in this vicinity. Such, however, is not the case. Nearly all the rocky strata within an area of twenty miles of Philadelphia will yield water whether the rocks be mica schist, syenite sandstone or limestone. Occasionally you may find a locality that is barren, but this is rarely the case.

A comparison of the wells drilled in Europe and in this vicinity may be of interest. The wells drilled abroad have furnished an abundance of water for the supply of cities. At Grenelle, near Paris, a well was drilled to a depth of 1,798 feet, when the water stratum was reached a column of water rose in the well that furnished 36,000 gallons per hour, the entire water supply of a suburb of Paris. The well drilled at Passy has a diameter of 2 feet 4 inches and is 1,900 feet deep. From this a column of water rose to the height of fifty-four feet and furnished 5,582,000 gallons per day. Many artesian wells have been drilled in the chalk strata around London. One well alone, at Chadwell near Ware, yielded London over 4,500,000 gallons per day toward its water supply.

The Kentish Town Water Works have a well nearly 1,000 feet deep. It is said there were two wells drilled at Chicago each five inches in diameter, one 1,000 feet and the other 700 feet deep, which furnished 800,000 gallons daily to the water supply. A well of three-inch bore and 2,000 feet deep was drilled at Louisville, Ky., and furnished nearly as much water as the deep well near Paris.

It may truthfully be urged that the geological formation of Philadelphia and vicinity is different from that of Paris and London, but the records of a few wells drilled in this locality will show that we have prolific water-bearing strata in Southeastern Pennsylvania. A well was drilled by the Oriental Bath Company, at 1104 Walnut Street, Philadelphia, through sixty-six feet of clay and 200 feet of mica schist and gneiss rock. It yields 6,000 gallons per hour and rises to within twenty-eight feet of the surface. The Pennsylvania Railroad drilled ten shallow wells near Radnor within a space of an acre to supply the water tanks and a pumping station. These wells when connected and tested by continuous pumping yielded 288,000 gallons per day. Deep wells at Radnor do not give much water. At Lansdale, along the North Pennsylvania Railroad, a few miles north of Philadelphia, there is no water supply except that derived from an artesian well. This well was drilled to a depth of 611 feet, and is cased or lined with iron pipe to a depth of 259 feet; with an improved pump, it could give 200 gallons per minute or 288,000 gallons per day. The supply is said to be practically inexhaustible. Lansdale is not a particularly good locality for water except at a great depth, because the clay slate, shale and sandstone are tightly packed and the water soaks slowly between the bed planes. The borough of Jenkintown is supplied with artesian water and is in the same belt of mica schist rock as Philadelphia wells. One well is 324 feet deep, the other is 349 feet deep. They will each yield 9,000 gallons per hour, and not only supply Jenkintown with water, but also the surrounding twenty villages for a distance of three miles. The water is soft. Artesian wells drilled in the mesozoic or new red sandstone at Newark, N. J., have yielded an abundance of water. Three wells of six-inch bore, and each less than 100 feet in depth, flowed at the rate of 250,000 gallons each per day. Another deeper well in the same city is yielding 800,000 gallons per day. This is a favorable locality, because the water-bearing stratum underlies a thick bed of clay. Wells drilled in the same belt of mesozoic sandstone at Norristown, Pa., yield over 3,000 gallons per hour with small pumps. Many other instances of prolific wells, such as those at Atlantic City and Ocean Grove, can be given; but enough has been said to show that we have water-bearing strata. Of course, it would be impossible to supply a city the size of Philadelphia wholly with artesian water, but in seasons of long-continued draught, such as the summer of 1892, when the rise of even a couple of inches in the reservoirs was eagerly noted, artesian wells would be an enormous gain. In a deep well, when a water crevice is struck near the bottom in drilling, it can be widened and the supply of water enormously increased by exploding nitro-glycerine in the wells in precisely the same manner that it is employed in the oil regions. Tin canisters containing the proper amount are lowered and exploded by means of electricity. The explosion widens the bottom water crevices.

The city of Philadelphia is underlaid with an immense deposit of clay which artesian borings have shown is fifty feet in thickness, and in many parts of the city much deeper. Clay is impervious to water, and this great clay bed checks to a great extent, although not wholly, the filtration of surface drainage. It must not be thought for an instant that the clay is a perfect barrier and wholly prevents the surface water from getting to the mica schist rocks beneath, because instances can be given of surface water getting below and showing on analysis. One fact then cannot be too strongly emphasized, artesian wells must be thoroughly cased with iron pipe from the surface, the deeper the better. When they are properly cased for 100 feet or more there is little if any danger from surface contamination. When the well is finished it should be pumped for a couple of hours, and the next day a sample taken for chemical analysis. If any trace of surface contamination is shown, the casing should be driven deeper until analysis proves the water to be perfectly pure. These precautions are only necessary in large cities and towns. Artesian wells drilled in the country will always yield pure water. A series of artesian wells drilled in Fairmount Park, some distance out, would yield an abundance of pure and wholesome water, which would be free from surface contamination of any kind.

A series drilled near the new reservoir at Roxborough would give the purest water. When artesian wells are drilled in solid rock in the country, it is not necessary always to line them with iron pipe, as a hard compact rock will remain open from top to bottom when once drilled.

PROCEEDINGS

OF THE

ELECTRICAL SECTION

OF THE

FRANKLIN INSTITUTE.

[*Stated meeting, held Tuesday, November 22, 1892.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, November 22, 1892.

Prof. Edwin J. Houston, President, in the chair.

Present, twenty-seven members and visitors.

The minutes of the previous meeting were read and approved.

The Treasurer reported the cash balance in the treasury, and presented bills for printing, which were approved and ordered paid.

Two nominations to membership were referred to the Committee on Admissions. The Committee reported two members elected since last meeting.

Nominations for officers for 1893 being in order, Prof. E. J. Houston was nominated for President for another term, but declined with regret on account of the press of other business. The following nominations were then made and duly seconded:

For *President*, ...	Mr. Elmer G. Willyoung.
For *Vice-Presidents*, ...	Prof. Edwin J. Houston, Mr. C. W. Pike.
For *Secretary and Treasurer*, ...	Prof. L. F. Rondinella.
For *Conservator*, ...	Dr. Wm. H. Wahl.

(*The election will take place at the December meeting.*)

Mr. E. G. Willyoung read a paper on "Some New Apparatus for the most exact Comparison and Adjustment of Resistance Standards and the Determination of Temperature Coëfficients." The paper was illustrated with some fine examples of the apparatus described, and was referred for publication.

Mr. O. T. Louis presented a communication on "Errors in the Determination of Areas from Measured Diameters." This was illustrated by a diagram and blackboard sketches, and was referred for publication.

Mr. Nelson H. Genung read a paper on "Recent Improvements in the d'Arsonval Galvanometer," illustrated by a fine instrument of the type made by Queen & Co., arranged in working order. Referred for publication.

The meeting then adjourned. L. F. RONDINELLA, *Secretary.*

RECENT IMPROVEMENTS IN D'ARSONVAL GALVANOMETERS.

BY NELSON H. GENUNG.

[*Read at the stated meeting of the Electrical Section, November 22, 1892.*]

To see an elaborate electrical instrument highly lacquered and polished standing in the show-case of some college laboratory is one thing; to see the same or a similar instrument in the working drawings or in a thousand and one pieces on the workman's bench ready for assembling is quite another thing. It is in the latter case only, when one sees here and there a part insignificant in itself but on which may depend the success of the instrument as a whole, that one is brought to realize the necessity of looking after the smallest details in instrument construction. It is certainly difficult for a person unacquainted with the manufacture of fine instruments to fully appreciate the range of electrical and mechanical knowledge which one must possess in order that he may plan the working drawings for a high-grade instrument which shall work satisfactorily when completed, which shall conform strictly to mathematical principles, which shall include in neat and attractive mechanical form all the latest improvements applicable to that particular type of instrument, and which shall, in so far as is possible, conform to standard sizes of material so as to reduce the cost of manufacture to a minimum. It is only by continuous study and practice that one acquires satisfactorily the knowledge necessary for such an undertaking.

A thorough and systematic study of the Deprez-d'Arsonval type of galvanometer has recently been made by the writer with the ultimate intention of throwing this class of instruments into a variety of forms for both the college and commercial trades. The paper presented to you this evening will include, among other things, an historical sketch of the Deprez-d'Arsonval galvanometer, a little mathematical reasoning concerning aperiodic galvanometers of this type.

a brief review of the most noteworthy improvements recently made in this class of instruments, and a detailed description of a d'Arsonval galvanometer, which, in the course of its design, has been thoroughly criticised from both a theoretical and mechanical standpoint, and which, although not yet fully completed, has yielded extremely satisfactory results.

A galvanometer is an elctrical measuring instrument in which use is made of the electro-magnetic properties of currents. A coil of wire traversed by an electric current sets up a magnetic field of its own, the strength of which at any point depends on the strength of the current flowing. Suppose this coil to be mounted vertically, and with its plane parallel to the magnetic meridian, a magnetic needle suspended in its axis will, when no current is flowing, assume a direction parallel to the horizontal component of the earth's field, but on introducing a current the needle will be deflected from this its zero position, through some definite angle depending on the relative strengths of the two magnetic fields involved. Thus we see that by this method the measurement of current is reduced to a measurement of the strength of field produced by it.

Numerous modifications may be introduced so that for a given strength of current the angular deflection of the needle may be materially increased. This increase in the sensibility, as it is called, has been brought about in several ways, such as decreasing the torsional control of the suspension fibre, reducing the moment of inertia of the movable parts, increasing the length of wire acting on the needle, reducing the mean distance of the coil from the needle and decreasing the strength of the earth's field in the vicinity of the needle by means of a control magnet. A discussion of these points being beyond the range of this paper will be omitted. Brief reference, however, will be made to the last one mentioned as it furnishes a stepping-stone to what is to follow concerning d'Arsonval galvanometers.

The extreme annoyance experienced in attempting to use a galvanometer of the above-described type, made sensitive by neutralizing the earth's effect on the needle by means of a control magnet is well-known. The original or earth's field and the temporary field set up by the control magnet being nearly equal and opposite in direction destroy, almost completely, each other's effect on the needle. A slight variation in strength or direction of either of these fields or the introduction of a third field, however weak it may be, is often sufficient to cause the needle to turn completely around. This subject received full and thorough treatment in a paper read by Mr. Elmer G. Willyoung,* at our last meeting.

It was mainly with the idea of obviating this difficulty that Marcel Deprez,† about the year 1880, introduced into galvanometer construction what has since proved an important and desirable modification. He placed the galvanometer needle between the poles of a powerful horseshoe magnet, thus freeing it from all local magnetic disturbances and giving it a short period of oscillation, but at the same time causing it to lose almost entirely its sensibility. He afterwards substituted a soft iron laminated needle which when placed in position became strongly polarized by induction. *Fig. 1* shows the general arrangement adopted by him, and known under the name "*galvanomètre à arête de poisson*," galvanometer of herring-bone work. The soft iron needle *A* is mounted within the galvanometer coil *B*, and both are surrounded by the horseshoe magnet *N S*.

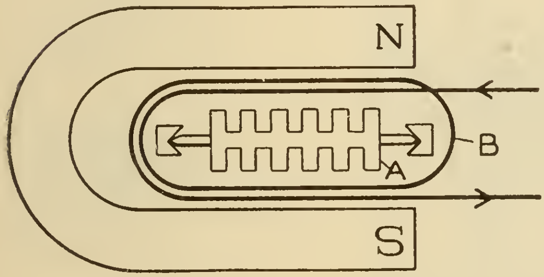

FIG. 1.

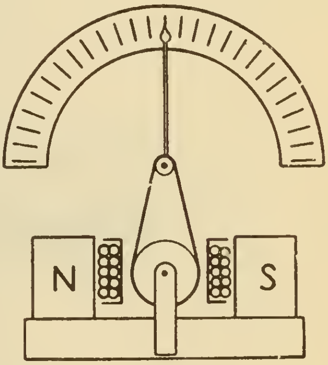

FIG. 2.

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* "A New Standard Ballistic Galvanometer with Variable Sensibility and without 'Drift,'" by Mr. Elmer G. Willyoung, New York *Electrical Engineer*, November 16, 1892.

† "On Electrical Measuring Instruments: Ammeters and Voltmeters," by Marcel Deprez, *La Lumière Électrique*, April 30, and November 5, 1881.

The range of movement of the needle is, however, very small and the deflections far from being proportional to the currents measured.

A multiplying device, similar to that shown in *Fig. 2*, was added a little later, which obviated these difficulties to a considerable extent. The scale was at that time usually divided into degrees, thus necessitating the use of a table of values or a calibration curve.

The next step was to retain this powerful control magnet and astaticise the movable system. M. d'Arsonval* concluded that so long as the moving parts contained any magnetic material this would be utterly impossible, the directing force being always very great as compared with the deflecting force. In order to accomplish this he aimed at making the directing forces very weak and the deflecting force very powerful, and succeeded by fixing the soft iron needle and making movable the current coil of the Deprez instrument. The general arrangement remaining the same, the number of parts was not materially increased. The control being non-magnetic could be made as weak as might be desired, the deflecting force remaining practically the same. *Figs. 3* and *4* show d'Arsonval's arrangement in which *N S* represents the permanent horseshoe magnet, the poles of which are thirty millimetres apart; *B*, the fixed soft iron tube or needle, about twenty-five millimetres outside diameter, which extends nearly the whole length of the magnet; *C*, the coil mounted on knife-edges *D D* and provided with mercury contacts *E E*, coinciding with the axis of rotation.

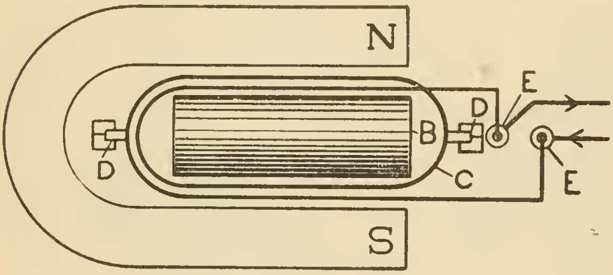

FIG. 3.

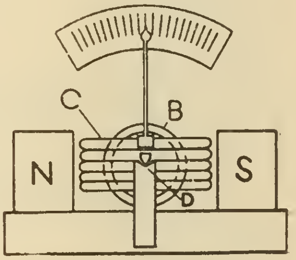

FIG. 4.

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* "A new Deprez-d'Arsonval Astatic Galvanometer," by M. Deprez, *La Lumière Électrique*, September 7, 1881.

Almost any desired sensibility may be attained by properly adjusting the centre of gravity of the movable system.

A few years later this galvanometer was constructed as shown in *Fig. 5*, by M. Carpentier, in which form it has practically remained to the present day.

Lord Kelvin probably first made use of the above principle in the construction of his siphon recorder used as a receiving instrument in submarine telegraphy. M. d'Arsonval* says regarding his own application of this principle: "This apparatus rests upon the same principle as does the siphon recorder of Wm. Thomson. It is seen that I have arrived at the same combination, starting from another point of view and that I have also transformed into a *galvanometer*, an apparatus which up to then had been used only as a telegraph receiver." In the same article he continues, "I have given to this apparatus the name of *Deprez-d'Arsonval galvanometer* in order to recall its origin."

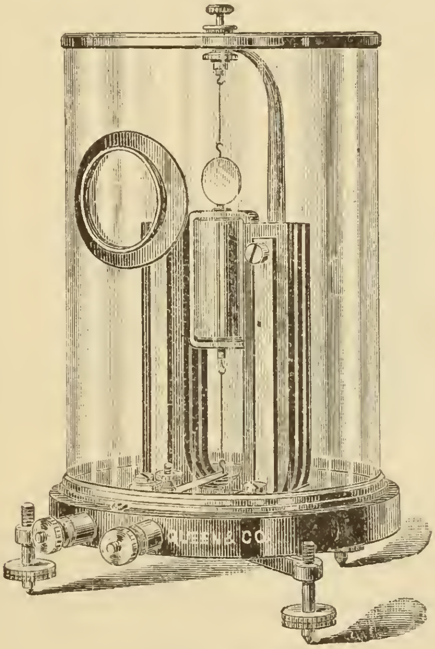

FIG. 5.

A successful attempt was made in 1884 by Deprez† to construct a d'Arsonval galvanometer giving proportional indications. In an article published by him at about that time he says, "The deflections of the needle are exactly proportional to the intensities of the current even when deflected 120°." Two soft iron pole pieces circularly cut out were employed. These pole pieces *B B*, see *Fig. 6*, and the soft iron cylindrical core *C* were rigidly attached to the magnet. Within the annular space occupied by the coil *A*, the magnetic field is strong and uniform and the lines of force are normal to the polar and core surfaces. The coil thus always moves through a uniform magnetic field, cutting the lines of force everywhere normally.

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* "Aperiodic Galvanometers of Great Sensibility," by M. d'Arsonval, extract *de la Revue Internationale de l'Électricité et de ses Applications*, April, 1886.

† "On a Galvanometer in which the Indications are Proportional to the Current Strength," by M. Deprez, *La Lumière Électrique*, December 13, 1884.

Another arrangement of pole pieces,* see *Fig. 7*, has been proposed which is capable of giving to the coil a much wider range of movement in a perfectly uniform field. This arrangement has, however, one or two disadvantages worth mentioning. The coil being pivoted at the centre *A*, has a comparatively large moment of inertia, which prevents it from coming to rest so quickly as it otherwise would. The amount of "dead" wire is also very great. By "dead" wire is meant all that portion of the coil not so disposed with reference to the field as to assist properly in the deflection, the "active" wire being that portion which moves properly in the magnetic field. This point is very satisfactorily illustrated in *Fig. 8*. The portions *L N* and *M R* in all three of the coils are so disposed, with reference to the axis of rotation and to the lines of force, as to assist in the deflection.

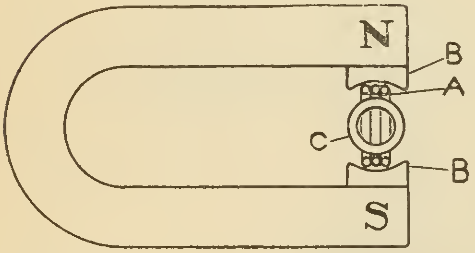

FIG. 6.

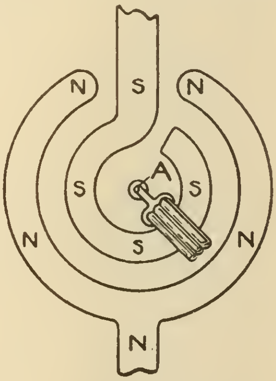

FIG. 7.

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* See *La Lumière Électrique*, March 24, 1888.

The wire making up these portions is called the "active" wire of the coils. The wire making up the portions *L M* and *N R* takes no active part in the deflection, and is, in consequence, called the "dead" wire.

In an instrument to be used merely as a current detector, the deflections being usually very small, it is desirable to concentrate the field as much as possible by employing convex or conical pole pieces, so as to give to the coil a maximum deflecting force. Square or concave pole pieces give a weaker field for the coil at the start, but as the deflections increase the active portions of the coil pass into a gradually increasing strength of field, which makes up for the loss in deflecting moment due to the shortening of the arm of the couple.

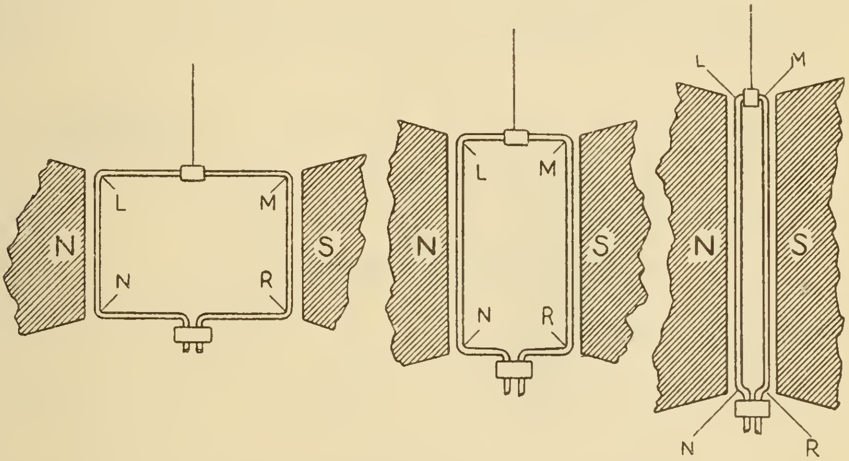

FIG. 8.

The leakage of the lines of force around the space occupied by the coil is likely to be much greater in horseshoe than in circular magnets, see *Figs. 9* and *10*. By adopting an arrangement similar to that shown in *Fig. 3*, nearly all the lines are utilized, but the great length necessarily given to the coil in order to capture the comparatively small number of lines near the bend in the magnet, is not a desirable feature in instrument construction. The iron core, however, doubtless tends to distribute the lines somewhat uniformly throughout its entire length. The increase in sensibility by this means is more than counter-balanced by the additional moment of inertia necessarily given to the coil, which shows that the lines might better be concentrated at or near the poles proper, circular magnets being employed to avoid any appreciable loss due to leakage.

A novel arrangement of coil and magnets has recently been adopted by M. Gaiffe,* of Paris, in milliampèremeter construction. He has done away with the soft iron core and makes the deflections proportional to the intensities by employing two magnets of cylindrical form, as shown in *Fig. 11*. The coil in this arrangement contains a large amount of "dead" wire, being necessarily quite broad, and has a considerable moment of inertia as well. The range of movement, also, is not materially increased.

Turning our attention now to the movable system we find that when the coil is deflected from its position of equilibrium there is a torsional couple due to the suspension which tends to bring it back. This is the only directive force brought to bear on the system. The moment of this couple is a function of the angle of deflection, and may be made almost anything desired by varying the length and cross-section of the suspension wire. Aside from this directive force, there are various retardative forces at work when the coil is in motion, due to the reaction of induced currents, friction with the air, and the like, which tend to bring the system to rest. These forces are functions of the angular velocity of the system.

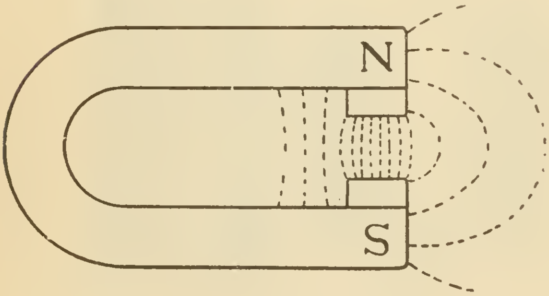

FIG. 9.

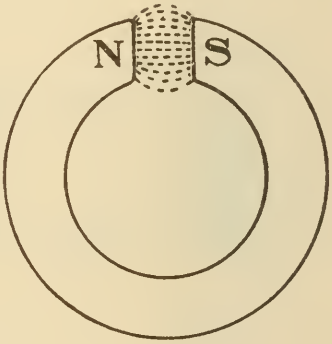

FIG. 10.

In the movement of the coil of a galvanometer of this type we have an example of the rotation of a solid about an axis in which case the product of the angular acceleration by the moment of inertia of the movable system is equal to the sums of the moments due to the directive and retardative forces. The differential equation for the movement of the coil thus becomes

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* *La Lumière Électrique*, September 3, 1892.

$$\Sigma m r^2 \frac{d^2 \theta}{d t^2} + A \frac{d \theta}{d t} + B \theta = O$$

in which θ represents the angular deflection in time t, $\Sigma m r^2$ the moment of inertia of the coil, A a constant for the retardative forces and B a constant for the torsional couple.

Imagine now the retardative forces to become negligable, the coil, when set in motion, acquires the same velocity every time it passes its position of equilibrium and makes a series of perfectly identical oscillations. It is thus said to have a *periodic* movement. The time of oscillation of the coil may be greatly increased, either by increasing its moment of inertia or by decreasing the directive moment due to the suspensions, the oscillations still remaining isochronous.

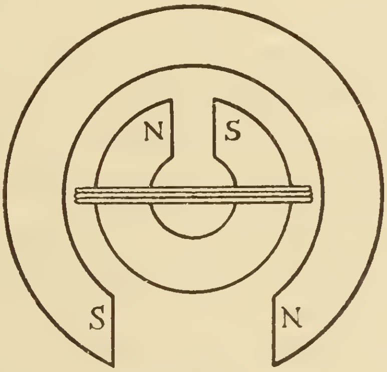

FIG. 11.

If, now, B is left constant and A made to increase gradually, the period becomes greater and greater as the logarithmic decrement increases. Finally, A having attained a considerable value, due to self-induction in this case, the coil on being drawn to one side and released, returns to its position of equilibrium, moving rapidly at first then more and more slowly, finally coming to rest. Infinite time is required theoretically for accomplishing this; practically, however, the zero point is reached in the course of a few seconds.

Suppose the only damping effect on the needle to be that due to induction; A is then equal to

$$\frac{F^2 S^2 n^2}{R}$$

where F represents the strength of the field; S, the area of the coil; n, the number of turns composing it, and R, the total resistance in circuit. Since the value of A depends on the total resistance R as the only variable, the field remaining constant, it should become zero when R reaches infinity; that is, when the coil is on open circuit. As a matter of fact, however, A does not become zero quite since the damping, due to friction with air, is not wholly negligable. By decreasing R the value of A increases and the coil finally assumes an *aperiodic* movement. A solid rotating about an axis is said to have an "aperiodic" movement when it takes up its new position immediately and without oscillation. By setting a d'Arsonval galvanometer coil of low resistance to oscillating on open circuit between the poles of a powerful horseshoe magnet, the transition from the periodic to the aperiodic movement is easily followed, as the circuit is closed through a high external resistance which is gradually reduced until the coil is short-circuited.

Time will not be taken to go more deeply into the theory of this instrument, as there are many points of more interest and greater importance which should be taken up. The theory of aperiodic galvanometers of the Deprez-d'Arsonval type has been thoroughly reviewed and experimentally verified by M. Ledeboer,* to whose paper the reader is referred in case he desires to go more deeply into the theoretical reasoning.

As early as 1881, Deprez† speaks of short-circuiting the coil for the purpose of damping the oscillations. The only resistance in circuit then being that due to the coil, the currents induced are sufficient to bring the needle slowly to rest. Closing the article, Deprez says: "This characteristic makes the instrument applicable to the measurement of resistances."

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* "Theory of Aperiodic Galvanometers," by M. Ledeboer, *Journal de Physique*, second series, vol. vi, p. 53, 1886. Also *La Lumière Électrique*, June 26, 1886.

† "New Deprez-d'Arsonval Astatic Galvanometer," by M. Deprez, *La Lumière Électrique*, September 7, 1881.

In the well-known Weston instrument, constructed on the Deprez-d'Arsonval plan, the coil is wound on a copper frame which serves the purpose of damping very effectively. This frame acts the same as would a single turn of heavy wire dead short-circuited on itself, and moving as it does in a powerful magnetic field the inductive effect is sufficient to make the instrument practically "dead beat."

Weston has also proposed the electrolytic deposition of a layer of copper over the entire surface of the coil, which shall serve the same purpose. Ayrton and Mather* have encased the coil of their recently constructed d'Arsonval in a silver tube, which serves both as a damper and as a protection to the coil. The coil is rigidly attached to this tube, which forms a part of the movable system.

Numerous other modifications of this method for damping have been proposed, such as short-circuiting any number of turns on the coil, adding a separate coil which shall be short-circuited, providing a copper disc which shall rotate properly between the poles of a powerful magnet, and the like, all of which are amply sufficient for the purpose.

Apparently no particular attention was paid to the best form of coil to be used in d'Arsonval galvanometers at the time when the best shape of pole pieces was being so thoroughly studied. In a paper on galvanometers, by Messrs. Ayrton, Mather and Sumpner,† the conclusion is drawn that the most sensitive galvanometer attainable is one of the d'Arsonval type suitably modified. For accomplishing this they say that the pole pieces should be very close together, the coil very small and no stationary iron core employed. The sensitiveness could be further increased by employing electro-magnets instead of permanent ones.

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* "The Ayrton-Mather-d'Arsonval Galvanometer," *London Electrician*, July 29, 1892.

† "On Galvanometers," a paper read before the Physical Society, *London Electrician*, February 7, 1890.

The coil should also be long and narrow and the controlling force reduced to a minimum whenever great sensibility is desired.

Mr. Mather,* a little later, presented a paper before the Physical Society, in which he exhibited the results of a thorough study on the best section of coil perpendicular to the axis of rotation. Quoting from this article: "Since for a constant period the controlling moment at unit angle must be proportional to the moment of inertia, the problem is to determine the shape of the section so that the ratio of the deflecting moment to the moment of inertia may be a maximum." The six sections shown in *Fig. 12* are taken from the above-quoted article. In *A* the deflecting moment per unit moment of inertia is 1·02, in *B* it is ·80, in *C* ·97, in *D* ·44, in *E* ·47 and in *F* ·40. Coil *A* is, as may be seen, more efficient than any of the others. These calculations are based on coils in which the length is great in proportion to the cross section.

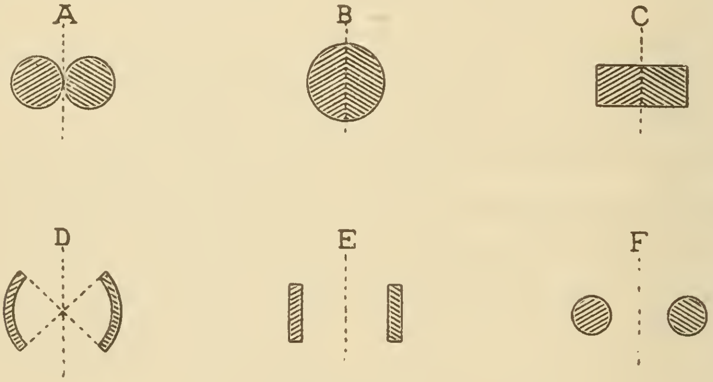

Fig. 12.

As to the kind of wire to be used in these coils nothing in particular need be said. Copper is usually employed the same as in most galvanometers of the various other types. If, however, the accuracy of the instrument depends to any considerable extent on the permanency of its resistance, it is better to employ a wire, having a much lower temperature coëfficient although its resistance may be considerably increased.

As has already been pointed out, the coil of the d'Arsonval galvanometer in its earliest form rested on knife-edge supports, and was provided with mercury cup connections and gravity control. In the Carpentier arrangement the coil was mounted on a vertical axis. The suspensions in this latter case being of wire served the threefold purpose of suspension, conductor and control. A little later, long spiral springs were employed as conductors and control the coil being supported by means of a cocoon fibre.*

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* London *Electrician*, April 11, 1890.

Suspension wires in a variety of sizes, shapes and materials have been employed at various times. Silver, platinum, silver-platinum, platinoid, German silver and phosphor-bronze are all materials for this purpose, the phosphor-bronze being on the whole the best, as it is little likely to corrode and is the least likely to take a permanent "set," thereby causing a slight change in the "zero point." The variation in sensibility due to the "time change," is also very small in the case of phosphor-bronze suspensions.

Flat strips possess a much smaller control than do round specimens of the same material having the same area of cross section. A suspension having a rectangular cross section the breadth of which is five to ten times the thickness has been recommended as the best form to adopt whenever a minimum control is desired. All other conditions remaining the same, Prof. Ayrton concludes that a flat strip suspension will give a deflection five times as great as will a round suspension of the same cross section. The liability to error due to a shifting of the "zero point," the result of a slight permanent "set," is much reduced by employing the strip. The radiation surface is at the same time considerably increased, this being often a matter of great importance in cases where very fine suspensions are necessary.

For commercial work the coil is usually supported in jewel bearings, springs serving for both control and conductors. In the well-known Weston instrument and in the milli-ampèremeters recently placed on the market by Mr. Gaiffe, flat spiral springs made from phosphor-bronze strip have been adopted.

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* *La Lumière Électrique*, 1887, p. 530.

In Prof. Ayrton's article, to which reference has previously been made, is described a form of d'Arsonval galvanometer having a coil of platinoid wire, the cross section of which is the same as that shown in *A*, *Fig. 12*, the iron core being necessarily absent. In this form the coil, mountings and frame work supporting the same are bodily removable from the instrument. A d'Arsonval galvanometer, designed by Messrs. Ayrton and Mather, was exhibited for the first time at a recent meeting of the Physical Society. This instrument, as you can readily see from the one before you, employs the narrow coil mounted in a silver tube, which forms a part of the movable system, and is suspended by a flattened phosphor-bronze wire. A button presses against the side of the silver tube by means of a spring which preserves the system from injury, when transportation is desired. The magnet is of one piece of metal, and has square pole faces. The movable system is mounted in a brass tube which may be removed, and another tube containing another coil slipped in place. The mirror cage and clamping device are both attached to this tube. The total height of the instrument is 6 inches, length of suspension tube 5¾ inches, outside diameter of magnet 4 inches, length of coil 2 inches, and diameter of silver tube ¼ inch. The coil has a period of about one and one-fourth seconds and is damped by the silver tube sufficiently to bring it to rest with about five complete oscillations.

We will now turn our attention to the new Queen-d'Arsonval galvanometer, this being its first appearance outside of their factory and electrical laboratory. *Fig. 13* shows the assembled instrument. All the parts are of rigid construction, and the instrument, as a whole, while it presents a pleasing appearance, presents a rugged workshop-like appearance as well.

The magnet has an outside diameter of four and one-half inches, and is built up of thirty-five discs one-tenth of an inch thick held together by means of three bolts. These discs are cut from the best sheet steel obtainable and are hardened glass hard. After having been thoroughly magnetized great care is exercised not to subject them to any rough usage. The magnet rests on a sheet of hard rubber *A*, *Fig. 14*, which insulates it completely from the metal tripod base. The pole faces *BB* are concaved, thus tending towards uniform deflections. At the same time the corners are slightly rounded, thus avoiding too great a leakage around the coil. The suspension tube *C*, sixteen inches long over all, slides freely between the poles, which, together with the mirror cage *D* attached to them, hold it rigidly in position. This tube containing the entire system may be slipped out without the necessity of loosening a single screw and another tube put in place. Connections are made automatically by means of sliding contacts

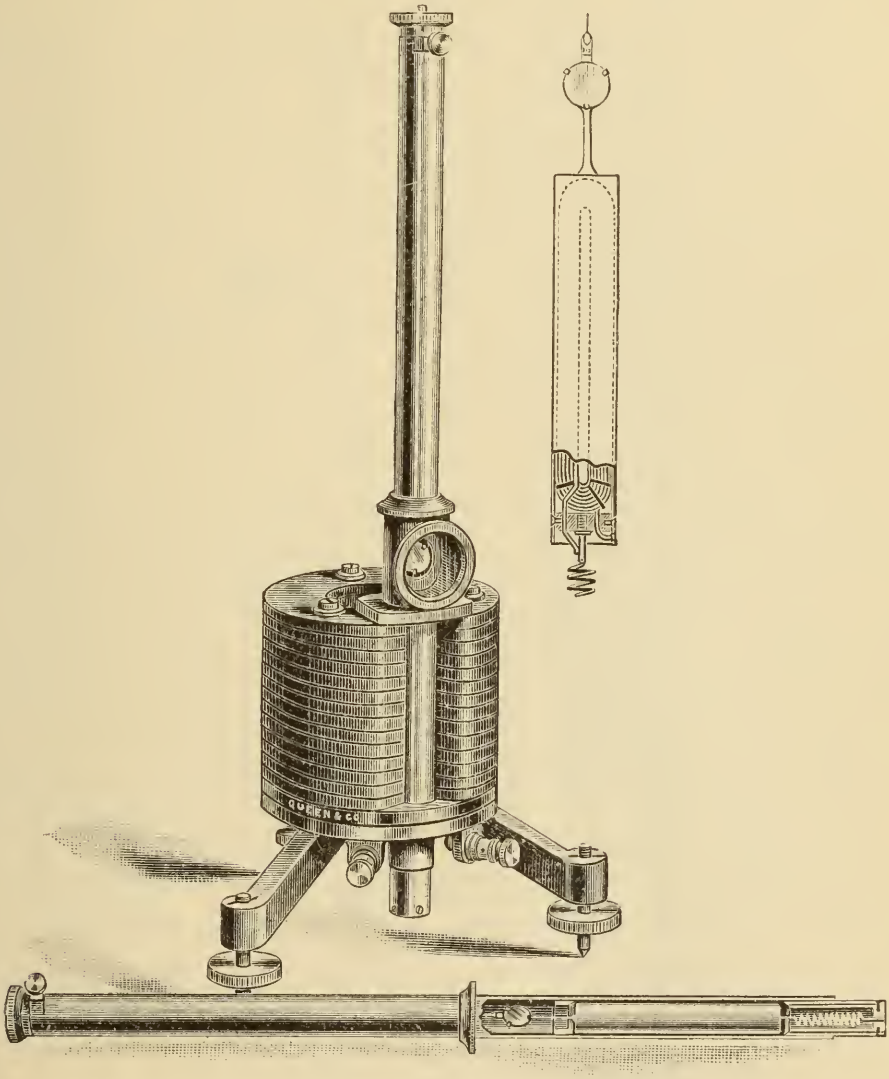
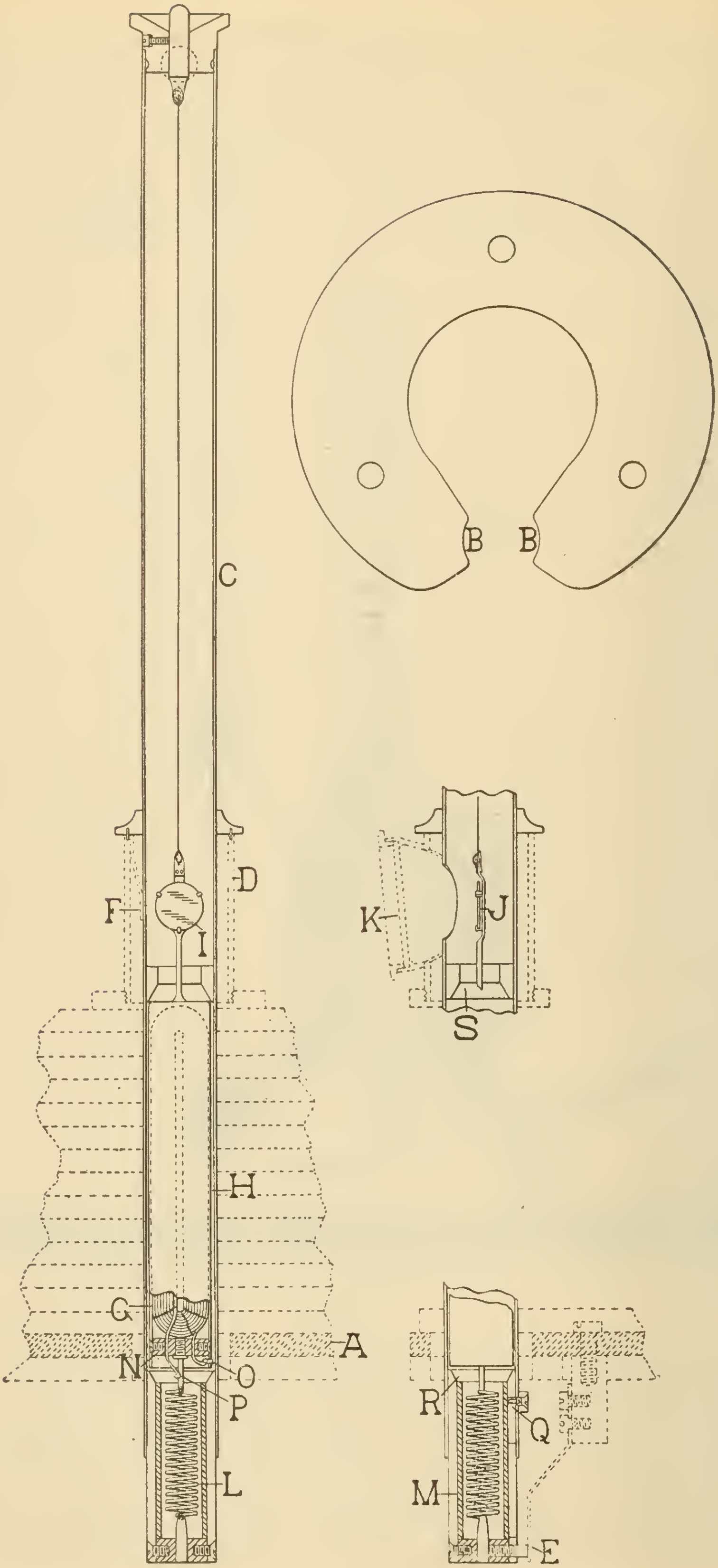


FIG. 13.



B

FIG. 14.

at *E* and *F*. The coil *G* fills the aluminum tube *H*, to which it is rigidly attached. The space within this tube allotted to the coil is 3½ inches long by $\frac{9}{16}$ inch in diameter. The coil itself has a cross section represented by two tangential circles, as shown in *Fig. 8*, this being the most approved shape. It may be wound either of copper, or of platinoid wire as may be desired. To the top of the aluminum tube is attached the mirror *I*, held in place by a three-armed aluminum clip, thus avoiding the use of wax. The silvered surface of this mirror lies in the axis of rotation as shown at *J*, thus eliminating one source of error usually overlooked in galvanometer construction. The glass window *K* of the mirror cage is tilted, as shown, so as to avoid reflection of the scale from its surface into the telescope. The suspensions may be of any desired material. Flattened phosphor-bronze wire is, however, usually employed, a long spiral spring *L*, forming the lower connection. The portion of the tube surrounding the spiral has a hard rubber lining *M*, which avoids all possibility of short-circuiting. The terminals of the coil pass through the hard rubber base *N*, of the aluminum tube, one being soldered at *O*, to a copper plug riveted into the side of the aluminum tube, and the other at *P*, to the projection to which the spiral spring is attached. The lower end of this spiral is electrically connected, by means of the platinized spring contact *E*, to one binding post. The other binding post is reached through the aluminum tube, the upper suspension, the suspension tube, the platinized contact at *F*, the mirror cage *D*, and the magnets. The lower end of the suspension tube makes sliding contact with the tube proper, its range of movement being limited by the slot and pin at *Q*. As a means for clamping the system, the upper edge of this sliding portion is reamed out, as shown in the figure at *R*, and just above the aluminum tube is fastened a collar *S*, similarly shaped. When the lower end of the tube is shoved up, the coil is not only clamped but lifted slightly as well, thus entirely relieving the suspension wire of all strain. By this means the coil is held perfectly rigid during transportation without the least fear of injury to any part of the system.

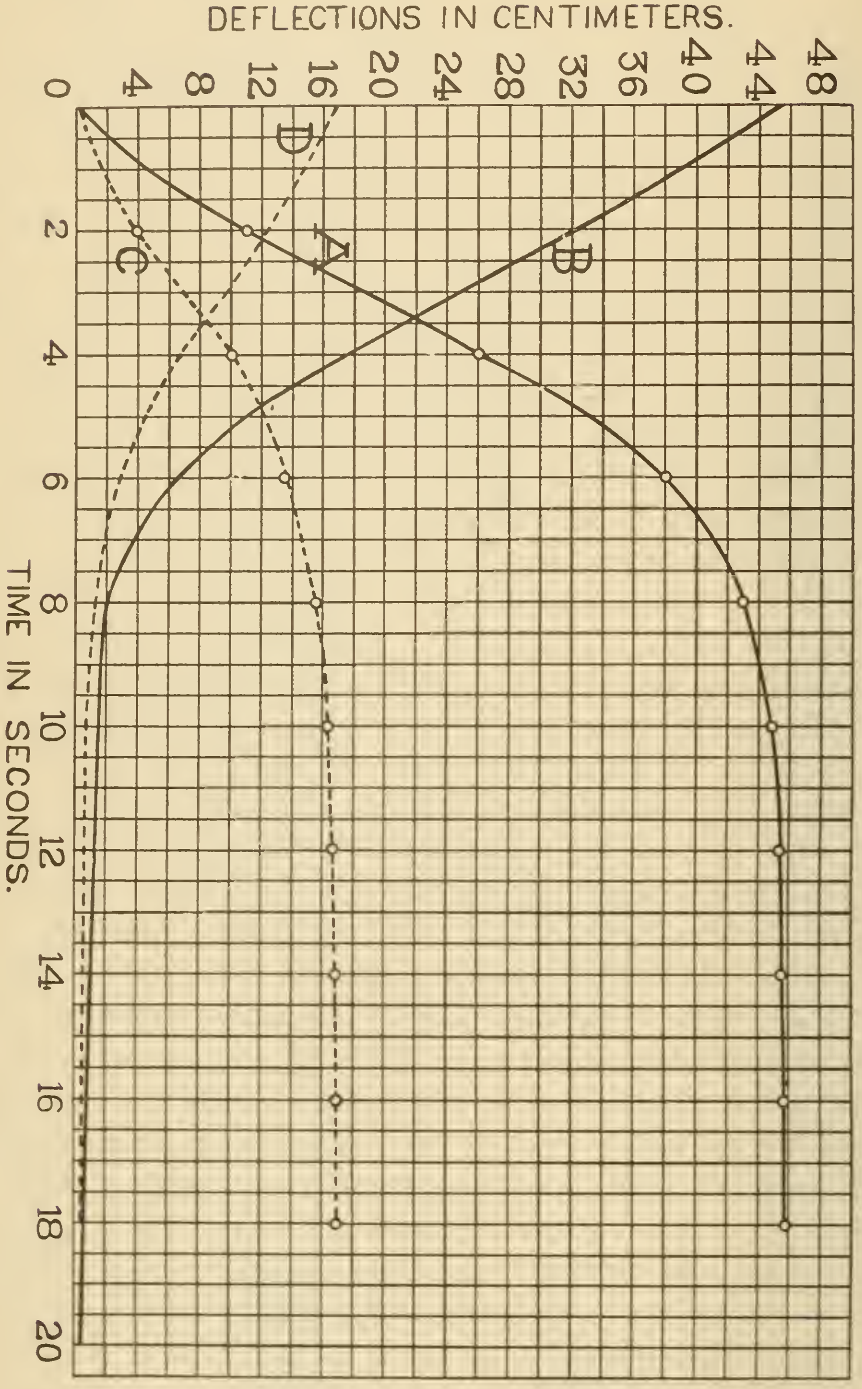


FIG. 15.

Starting the coil of this instrument from a position of rest, its position was noted every two seconds until it had again come completely to rest. The curves, *Fig. 15*, are intended to represent this movement. Curve *A* was obtained by closing the circuit through a resistance sufficient to give about forty-six centimetres deflection. Curve *B* was obtained by breaking the circuit thus allowing the needle to return to zero. Curves *C* and *D* were obtained in a similar manner, the deflection being only about sixteen centimetres. From

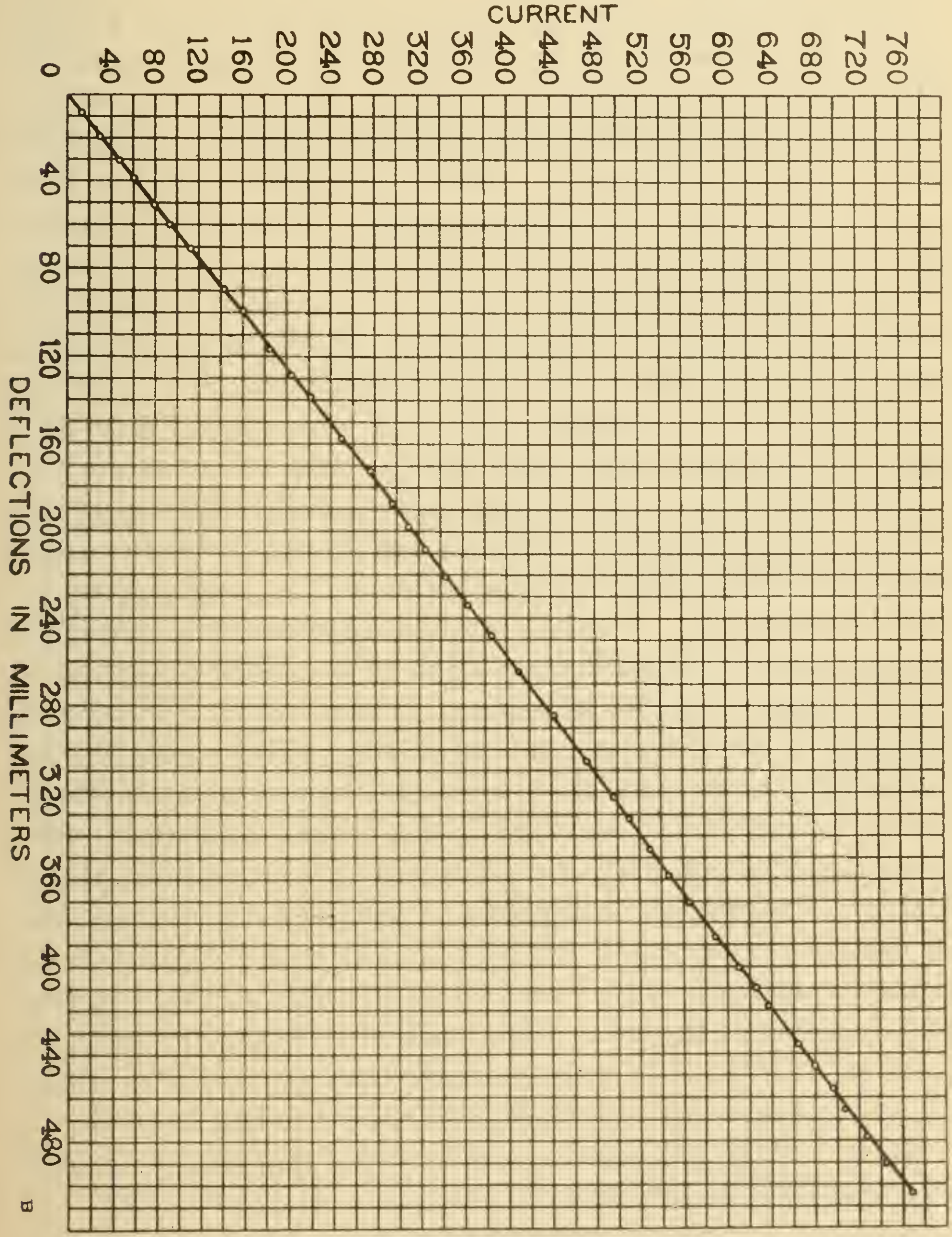


Fig. 16.

these curves it is easily seen that the movement of the coil is absolutely aperiodic; that is, it moves directly to its position of rest, approaching it more and more slowly, without showing the least sign of an oscillatory movement.

The curve, *Fig. 16*, is practically a calibration curve of the instrument. Abscissæ show the deflections in millimetres on a scale placed at a distance of one metre and the ordinates the corresponding currents. To obtain the values of the currents in fractions of an ampère multiply the ordinate readings by ·00000001. This curve, practically the first one yet taken from the instrument, is very nearly a straight line curve which shows that the readings on a straight scale are very nearly proportional to the currents producing them.

The coil employed in obtaining the above data was wound with No. 36 copper wire, single silk insulation, having 694 turns and a resistance of 178 ohms. Its size and shape were as previously mentioned. The suspension was of platinum silver wire, 0·0014 inch round, and the spiral spring at the bottom was of the same material 0·0019 round. Phosphor-bronze strip has been delayed in reaching us in time for the paper. A small amount, however, has just been received and given the barest trial. The width of this strip is 0·006 inch and the thickness 0·0005 inch. The round platinum silver suspension and spring being replaced by this phosphor-bronze strip made the instrument much more sensitive, one volt pressure through 200 megohms now giving a deflection of one millimetre on a scale one metre distant. Under these conditions about fifty-five seconds are required for the coil to deflect and about forty for it to return to zero, which shows that a perfect aperiodic movement has been attained. The damping effect can easily be modified, so that this extremely slow movement will by no means appear as an objectionable feature to the instrument.

Extra tubes containing coils and suspensions of any desired material, resistance, etc., are supplied with the instrument. Tubes containing coils intended for ballistic purposes are also supplied. These latter are free from damping due to induction, a short-circuit key being amply sufficient to stop all movement of the system whenever desired

The work on d'Arsonval galvanometers is being continued with the intention of getting out an instrument of this type which shall have an extremely high sensibility, rivalling that of the Thomson square pattern galvanometer. The results thus far are very encouraging, and within a few months you may hope to see this instrument in tangible form.

ERRORS IN THE DETERMINATION OF AREAS FROM MEASURED DIAMETERS.

By O. T. Louis.

[*Read at the meeting of the Electrical Section, held November 22, 1892.*]

In scientific determinations made at the present day, the accuracy of the determination is the paramount question. The problem is not to measure a length to ·01 millimetre or a resistance to ·0001 of an ohm, but to determine a length or a resistance with an accuracy of ·01 or ·001 of one per cent. Little improvements often increase accuracy to a marked extent. To one of these little wrinkles, I would call attention to-night.

In some recent work in the measurement of conductivity at Queen's Laboratory at Ardmore, I had occasion to study the methods of determining the cross section of the specimens in question. The area could be determined in two ways: by calculation from the volume obtained by the determination of the mass and specific gravity and by calculation from a directly measured diameter. The latter method is of course the simpler and where a good chemical balance is absent the only one to be employed. To call attention to a few points to be observed in this latter method is the object of this paper.

Let δ equal the true diameter of any geometrical cross section, the area of which is to be determined.

Then $k\,\delta^2$ can be taken as the area of that cross section, k being a constant varying from

$$1 \text{ to } \frac{\pi}{4}$$

for all figures from the square to the circle.

In measuring a diameter by micrometer calipers two things may occur: the diameter may be measured too large by slightly twisting the calipers or by the presence of bends, or made too small by crushing the surfaces measured. Let the error thus made be called a. Then the measured diameter is

$$(\delta \pm a) \qquad (1)$$

and the area becomes

$$k\,(\delta \pm a)^2 \qquad (2)$$

the true area being

$$k\,\delta^2 \qquad (3)$$

and, therefore, the error is

$$k\,\delta^2 - k\,(\delta \pm a)^2 \qquad (4)$$

and the percentage of error is

$$\frac{k\,\delta^2 - k\,(\delta \pm a)^2}{k\,\delta^2} \qquad (5)$$

Simplifying expression (5) we obtain

$$\frac{\delta^2 - (\delta \pm a)^2}{\delta^2}$$

$$\left.\begin{array}{l} \therefore\ \dfrac{\delta^2 - \delta^2 - 2\,a\,\delta - a^2}{\delta^2} \\ \\ \text{and} \\ \\ \dfrac{\delta^2 - \delta^2 + 2\,a\,\delta - a^2}{\delta^2} \end{array}\right\} \qquad (6)$$

or

$$\frac{2\,a\,\delta + a^2}{\delta^2} \qquad (7)$$

$$\frac{2\,a\,\delta - a^2}{\delta^2} \qquad (8)$$

From expression (7) will be seen that when the diameter is measured too large, then the percentage of error in measuring the area is

$$\frac{2\,a\,\delta + a^2}{\delta^2} \qquad (7)$$

and the percentage of error when the diameter is measured too small

$$\frac{2\,a\,\delta - a^2}{\delta^2} \tag{8}$$

A comparison and discussion of expressions (7) and (8) bring out several interesting points.

The percentage of error in measuring the diameter is

$$\frac{a}{\delta}$$

in measuring the area the maximum error is

$$\frac{2\,a\,\delta + a^2}{\delta^2}$$

the ratio of the two errors is, therefore,

$$\frac{2\,a\,\delta + a^2}{\delta^2} \times \frac{\delta}{a} = \frac{2\,\delta + a}{\delta} \tag{10}$$

Expression (10) may be given the form

$$2 + \frac{a}{\delta} \tag{11}$$

Expression (11) shows us two interesting facts. First, when the diameter is measured greater than it really is then the minimum ratio of the error of area to diameter is 2, and the maximum ratio is 3. a is generally small compared with δ. This brings out the fact that the common opinion that the error in the area is equal to the square of the error in the diameter is erroneous Expression (11) shows that the actual error is never far from double the error of the diameter.

Hitherto we have been considering the case when the measured diameter is greater than the actual. Let us consider expression (8) in which the measured diameter (due say to crushing) is less than the actual diameter. In this case we have the percentage of error as

$$\frac{2\,a\,\delta - a^2}{\delta^2}$$

If we divide this by

$$\frac{a}{\delta}$$

we obtain as before the ratio of the error of area to the error of the diameter.

$$\frac{2\,a\,\delta - a^2}{\delta^2} \times \frac{\delta}{a} = \frac{2\,\delta - a}{\delta} = 2 - \frac{a}{\delta} \qquad (12)$$

From expression (12) we see, as before, that the ratio is not far from 2, but is always less than 2.

A comparison of expressions (7) and (8) will bring out an interesting fact. From (7) we have

$$\frac{2\,a\,\delta + a^2}{\delta^2}$$

from (8) we have

$$\frac{2\,a\,\delta - a^2}{\delta^2}$$

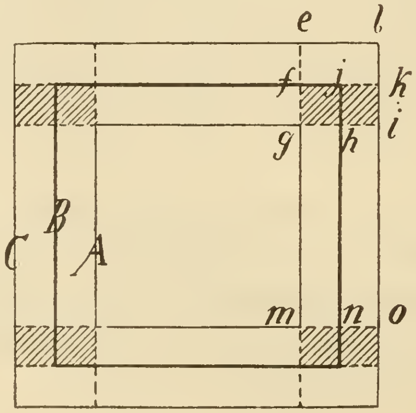
the difference is therefore

$$\frac{2\,a^2}{d^2} \qquad (13)$$

In other words, admitting the same error, we gain

$$\frac{2\,a^2}{d^2}$$

by crushing the wire by an amount a, to having the calipers too loose by the same amount a.



The same thing can be shown more clearly graphically. Let us take the special case of a square, as that permits of simpler demonstration. Three squares are shown, A B

C; B is the correct area we desire to measure; C is the measured area when the calipers are too loose; A when the calipers crush the surface to be measured. The diameter of C is $B + a$. Of A is $B - a$. The errors in measuring the areas are the bands between A and B and between B and C. An inspection of the diagram shows that the band $g\ h\ m\ n$ is balanced by the band $h\ n\ o\ i$; the corner $f\ j\ h\ g$ by $j\ k\ h\ i$: but the part $e\ l\ f\ k$ is unbalanced. Similarly for each corner we have a part equal to $c\ l\ f\ k$; therefore, the total area between B and C exceeds the total area between A and B by $4\ c\ l\ f\ k$. But $c\ f\ l\ k$ has the dimensions $\frac{1}{2}\ a \times a$ therefore

$$4\ c\ l\ f\ k = 4\left(\tfrac{1}{2}\ a \times a\right) = 2\ a^2$$

or the error in measuring the area as C is $2\ a^2$ greater than in measuring it as A; the error percentage gained being

$$\frac{2\ a^2}{d^2}$$

as shown above. Summing up the foregoing it follows that it is always an advantage to screw up the calipers quite tightly as even if the surface is slightly crushed something

$$\left(\frac{2\ a^2}{d^2}\right)$$

is gained over having the calipers too loose by the same amount a. This rule I have found especially advantageous to use when measuring the conductivity or specific resistance of wire. The surfaces to be measured are in this case generally of sufficiently hard material to prevent any serious crushing by screwing up the calipers tightly. On the other hand, there is a strong probability that if this is not done the kinks and bends which will exist, no matter how carefully the wire be straightened, will increase the apparent diameter. The usual precautions should of course be observed; *e. g.*, the determination of the mean diameter by reading along the whole length of the specimen under examination, test of the zero, etc. By observing these precautions the probable error can be reduced so as not to exceed the errors made in the measurement of the resistance.

ARDMORE, Pa, November 22, 1892.

Franklin Institute.

[*Proceedings of the stated meeting held Wednesday, Dec. 21, 1892.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, December 21, 1892.

MR. JOS. M. WILSON, President, in the chair.

Present, 195 members and twelve visitors.

Additions to membership since last report, twenty-seven.

The following nominations were made :

For *President*	(to serve one year), . . .	JOSEPH M. WILSON.
" *Vice-President*	(" three years), . . .	CHARLES BULLOCK.
" *Secretary*	(" one year), . . .	WM. H. WAHL.
" *Treasurer*	(" " "), . . .	SAMUEL SARTAIN.
" *Auditor*	(" three years), . . .	SAMUEL H. NEEDLES.
" "	(in place of Wm. A. Cheyney, deceased), .	FRANCIS LECLERE.

For the *Board of Managers** (to serve three years).

CHARLES H. BANES,
F. LYNWOOD GARRISON,
WASHINGTON JONES,
ISAAC NORRIS,
THEODORE D. RAND,
STACY REEVES,
COLEMAN SELLERS,
S. LLOYD WIEGAND,
J. Howard Gibson.

For the *Committee on Science and the Arts** (to serve three years),

ARTHUR BEARDSLEY,
HUGO BILGRAM,
FRANK P. BROWN,
JOHN H. COOPER,
N. H. EDGERTON,
G. M. ELDRIDGE,
F. L. GARRISON,
REUBEN HAINES,
JOHN HALL,
ARTHUR KITSON,
E. F. MOODY,
E. ALEXANDER SCOTT,
COLEMAN SELLERS,
H. W. SPANGLER,
WILLIAM H. WAHL,
Elmer G. Willyoung.

Vacancies in the Committee on Science and the Arts, were filled by the election of Prof. L. M. Haupt, for the unexpired term of Mr. Hexamer, and Mr. C. O. C. Billberg in place of Mr. Hering.

Dr. Coleman Sellers followed with a paper on the "Priestman Engine."

Mr. Lockwood moved that the thanks of the meeting be tendered to Dr. Sellers and that the subject be referred to the Committee on Science and the Arts for investigation and report. Carried.

The Secretary's report embraced an account of a visit of inspection to the works of the Tacony Iron and Metal Works at Tacony, Philadelphia, where the process of manufacturing wire glass, and of electro-plating with aluminum the extensive iron work of the tower of the new City Hall were observed.

Adjourned. WM. H. WAHL, *Secretary*.

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* Retiring members in roman ; new nominees in italics.

JOURNAL

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OF THE STATE OF PENNSYLVANIA.

FOR THE PROMOTION OF THE MECHANIC ARTS.

Vol. CXXXV. FEBRUARY, 1893. No. 2

The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the *Journal.*

The PRIESTMAN ENGINE as manufactured in AMERICA.

By Coleman Sellers, E. D.

[*A paper read at the stated meeting of the Franklin Institute, held December 21, 1892.*]

Mr. Jos. M. Wilson, President, in the chair.

Mr. President and Members of the Franklin Institute:

Dr. Sellers:—In 1890, while in London, I found Prof. William Cawthorne Unwin, B.Sc., F.R.S., interested in his tests of a few internal combustion or explosion motors, using petroleum as fuel, which had been exhibited at the Royal Agricultural Society's Show at Plymouth, in 1889. He called my attention to the fact that among those exhibited, the Priestman engine (*Fig. 1*) not only had worked well, but in cost of running, a small engine of less than ten horsepower compared favorably with the best results that had been obtained from steam in large low-pressure engines under the most favorable conditions, the price of coal oil being in England in excess of its price in America.

On March 8, 1892, Professor Unwin read a paper on "Petroleum Engines," before the Institution of Civil Engineers, at 25 Great George Street, London. This paper (to be found on the file of this Institute), dwelling mainly on the Priestman engine, is so exhaustive as to questions of economy and efficiency as to leave no room for me to present any better statement on the same subject, further than to say, that I have myself tested the accuracy of many of Professor Unwin's figures. Changes since that time made in the Priestman engine, as manufactured in Philadelphia by a branch company for the American market, will be the motive in my presentation of the case now.

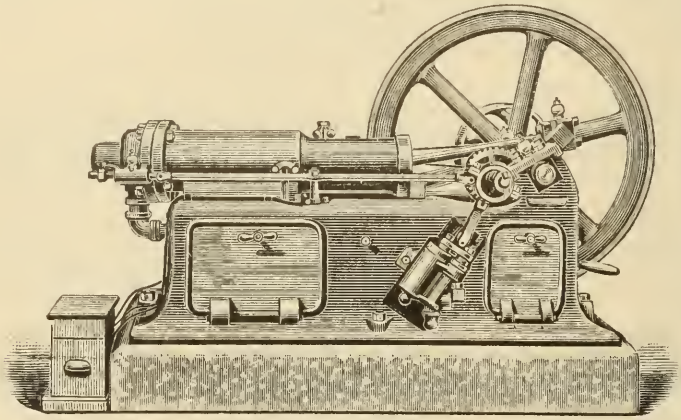

FIG. 1.—English design.

Professor Unwin's tests of consumption of oil by the Priestman engine, tried by him in England, extended over a considerable time, and he made these tests upon several different engines. In the tabulated results he gives the relative values of coal oil and coals as heat makers and their ability to yield power, the one, coal oil, applying its heat to air by internal combustion, the coal being burned under a boiler to make the steam that operates a steam engine.

He states that it may be assumed that one pound of oil is thermally equivalent to one and one-fourth pounds of coal;* so that 0·946 pounds of oil equals 1·18 of coal, 0·988 oil equals 1·23, and 0·842 pounds of oil equals 1·02 pounds of coal, each per effective brake horse-power per hour. He cites as the lowest observed consumption of steam, that a large triple-condensing Sulzer engine worked at high pressure gave a result equal to 1·61 pounds of coal per effective horse-power per hour. It is, indeed, remarkable that better results should have been obtained in an oil engine of only five horse-power, while a steam engine of five horse-power would be considered very economical that would consume three or four pounds of coal per effective horse-power per hour.

I have verified Professor Unwin's figures and have made several tests of consumption under unfavorable conditions to get at what may be considered the cost in actual use without any of the careful attention that always accomplishes trial runs with all conditions favorable. In one case, when an engine yielding 8·25 brake horse-power was run for two hours at full load, the engine being set up in an open shed, in very cold weather, with all conditions unfavorable, the oil consumption amounted to 1·159 pounds per horse-power per hour, the oil costing a little over four and three-fourths cents per gallon (say five cents per gallon), and was of a density of ·781; a cubic inch of this oil weighing ·028116 pounds. As 231 cubic inches, or one United

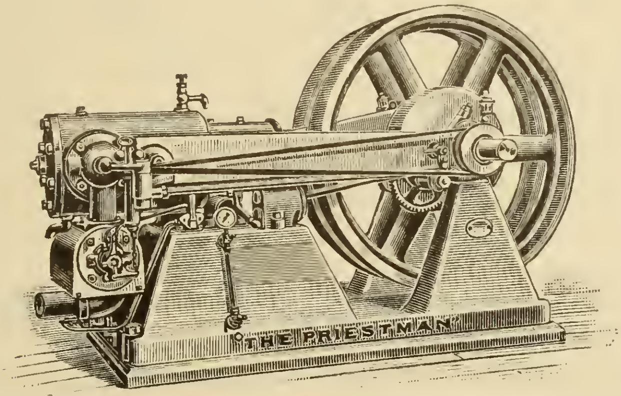

Fig. 2.—American design.

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* See Unwin on *Petroleum Engines*, p. 20.

States gallon costs (say) five cents and weighs 6·494796 pounds per gallon of this density, therefore, 1·159 of oil equals ·008923 of a dollar (say $\frac{9}{10}$ of one cent per horse-power per hour). This working at nine mills per horse-power shows that the claim usually made of assuming the cost to be one cent per horse-power is not unreasonable and may be considered as covering oil burned in getting up heat in the mixer before the engine is started.

Professor Unwin, on p. 25, gives a table of cost of working for fuel per hour, from which may be taken:

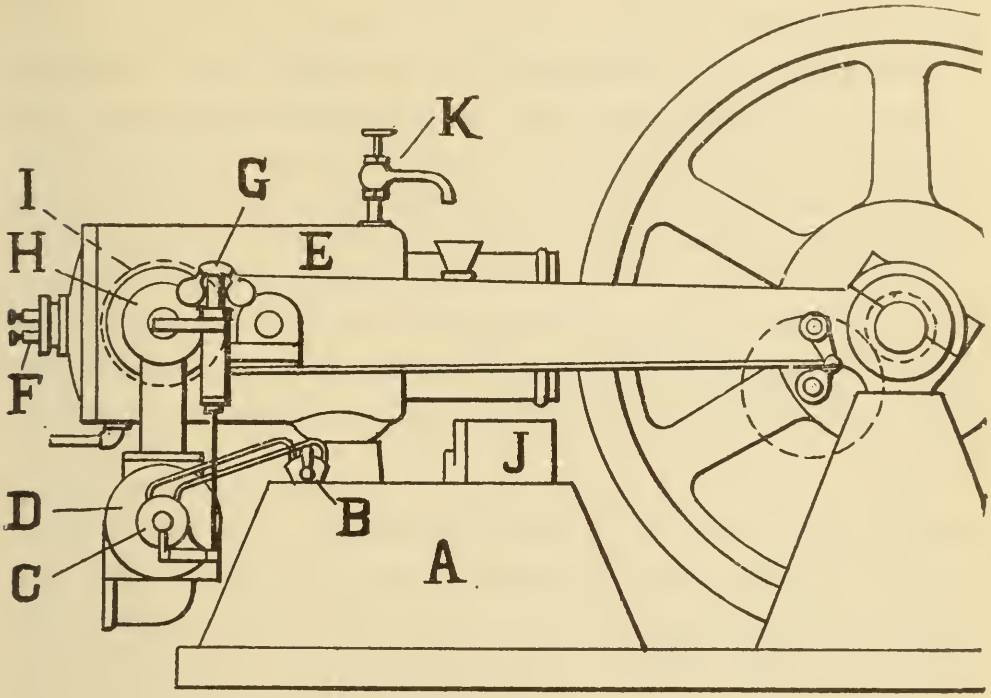
COST OF FUEL PER HOUR.

ENGINE.	PER EFFECTIVE HORSE-POWER.		
	Quantity of Fuel.	Price.	Cost.
Large condensing steam engine. . .	2 pounds.	$4 00 a ton.	·36 of a cent.
Small non-condensing steam engine.	6 pounds.	4 00 a ton.	1·08 cents.
Gas engine.	24 cubic feet.	1 50 per M.	3·60 cents.
Priestman engine.	1 pound oil.	2 38 barrel.	·75 of a cent.

With us, in the experiment cited, the Priestman engine was run at the cost of ·89 of a cent per hour. It must be borne in mind, however, that in a steam engine the cost of the stoker must be added, and most small steam engines use more coal than cited. There is also more fuel wasted in getting up steam or keeping up steam while standing than there is wasted in the oil engine, which requires no attention whatever while running, save to keep the oil in the tank, and when standing costs nothing.

The Priestman engine must not be compared with a steam engine and boiler as to first cost. It is a power-producing machine of a different type, considered as a superior and unique machine, and its real value is measured by deducting from its total first cost when erected all the savings it is capable of effecting as compared to power obtained from steam.

Professor Unwin, in his paper, mentioned the fact of these changes having been introduced in the American form of the Priestman engine, but did not go very deeply into the details of construction as he had not, at that time, seen the American machine.



SYSTEM OF OPERATION.

A, oil tank filled with any ordinary high test (usually 150° test) oil, from which oil under air pressure is forced through a pipe to the *B* three-way cock, and thence conveyed to the *C* atomizer, where the oil is met by a current of air and broken up into atoms and sprayed into the *D* mixer, where it is mixed with the proper proportion of supplementary air and sufficiently heated by the exhaust from the cylinder passing around this chamber. The mixture is then drawn by suction through the inlet valve *I* into the *E* cylinder, where it is compressed by the piston and ignited by an electric spark passing between the points of the *F* ignition plug, the current for the spark being supplied from an ordinary battery furnished with the engine, the *G* governor controlling the supply of oil and air proportionately to the work performed. The burnt products are then discharged through the *H* exhaust valve, which is actuated by a cam. The *I* inlet valve is directly opposite the exhaust valve. The *J* air pump is used to maintain a small pressure in the oil tank to form the spray. *K*, Water jacket outlet.

By this system a perfect combustion of oil takes place.

Fig. 1 shows the Priestman engine as examined by Professor Unwin, and you will observe that it differs in no respect from the ordinary engines that are made with the cylinder and bearings attached to a massive bed plate. In this case the bed plate is made hollow and has much of the working machinery within the casting, and inconvenient for repairs. Want of accessibility of the parts of the engine was the prime motive for some change in the American type, but not the only one. It is a necessity with all such machines in America that all parts shall be accessible; in fact, shall be visible and easily got at, and the changes that have been wrought in the American type of engine have been all in the direction of accessibility. It is with this engine as with the difference of American and English type of locomotive, and all that has been said in favor of the convenience of the American locomotive holds with equal force in reference to the convenience of the American type, which is shown in *Fig. 2.*

When, as in the English engine, the fly wheel is placed outside of the bearings and the shock from the sudden ignition comes upon the crank; that is, between the two bearings, the bearings receive this blow with almost full intensity; while with the Sweet straight-line principle, the fly wheels forming part of the crank, and offering their great weight to the blow between the bearings, they present a mass of sufficient inertia to neutralize the effect of the blow, and this is an illustration of the well-known case of the difference in personal comfort between endeavoring to crack a hickory nut on one's knee, with or without the intervention of a flat-iron or pound weight to serve as an anvil and neutralize the blow of the hammer.

When Mr. Albert Priestman, of the firm of Priestman & Co., came to Philadelphia to introduce the engine in America, he fortunately had for his advisers such able men as our fellow-members, our past president, Mr. Wm. P. Tatham, and Mr. Henry G. Morris. The latter called attention to what Professor Sweet was doing with his straight-line principle steam engine and explained the advantages to be gained by applying the same principles to an engine that at one period of its operation—at the instant of explosion—is subjected to a momentary strain several times greater for that moment, than can occur in a steam engine of the same nominal size from the steam acting expansively as supplied from a boiler. A petroleum engine of (say) ten horse-power at the moment of explosion may have its crank pin able to resist a force as great as that exerted by steam in a thirty horse-power steam engine, without being out of proportion. By adopting the Sweet principle of construction, the strength called for can be obtained at less cost than by the use of a crank of ordinary construction with other marked advantages, the built-up crank being, in my opinion, better than a solid crank, tooled out of a rough forging.

In this connection I must add that Professor Sweet, when consulted not only approved of what was proposed, but offered his help in constructing some parts of the first engines, so far as his own special machinery could be spared for the purpose.

When called upon for my opinion on the same subject, I endorsed all that Messrs. Priestman's advisers had recommended, and promised to present the American type (*Fig. 2*) of the engine to the notice of the Franklin Institute when the proper time should come.

This time has now come. In presenting the new form I do so with satisfaction, as it serves to illustrate the adaptation of a machine to the American market, which had already an established reputation in England for several years, with such marked deviations from the English model as to make the contrast striking.

This is one of the many examples of mechanical design modified to suit what at first may seem a question of the taste or fancy of a foreign market, but this reason for change is not the true one, and the lesson is rather instructive.

American machine tools differ in many respects from the English type from which they may have sprung, and in America has originated a new line of machine tools peculiar to the country and well adapted to the habits of our workmen. Some of these special tools favor construction in machinery not common in older countries, the opposition to the use of such tools coming partially from the conservatism of the workmen as well as from the difference in machinery used. In the present case, the readiness with which the engineers of the English house accepted the new type for the American market, speaks very highly for their good judgment, for in this machine, which is to be described to you, there are such marked deviations in form and arrangement of parts as to make the difference between the two machine designs not only very striking, but with this change in form of machine there has been, with the American engines from the start, a greater piston speed obtained and consequently higher efficiency for machines of the same weight and size of cylinder.

In bringing the Priestman oil engine to its present state of perfection, there must have been a long period of experimentation, and some of the changes will presently be noted, but all that has been established by the ingenuity of the originators and sustained by their careful experiments in England has been preserved in the American type, the difference being only in the general arrangement and disposition of the parts, as well as some changes in the material used, taking advantage of American experience in engine building generally, and that gained by the makers of this special engine during the period which has elapsed since the engines were first placed on the market.

Professor Unwin's paper was on "Petroleum Engines," and the engine we are considering this evening has been known as a petroleum engine, so also may any engine be called a petroleum engine, which uses petroleum or the products of petroleum, either as a fuel or as the motive-power of the engine. The name, however, conveys to the mind the idea that petroleum vapor is what operates the engine, which would be the case, if the petroleum was really expanded from a liquid into a gaseous form and used under pressure to act upon the piston of a steam engine, and as in point of fact naphtha engines act by the vapor of naphtha. When some portion of the petroleum product is consumed to vaporize another portion of the same product, and the gas so created does act expansively in the cylinder, and is afterwards condensed to be used over again, as in naphtha engines, such a process comes directly in the category of a petroleum or naphtha engine, and no other name could be well applied to it.

In the present case the petroleum is a fuel only. It is not vaporized so as to make a permanent gas, which can act expansively, but it does impart heat to air and renders it capable of performing the function of a true gas under pressure.

In the first place I wish to have you clearly understand the position in which the Priestman engine stands in relation to all others using coal-oil products, not only as regards its efficiency, but also as regards its absolute safety in fire risks, owing to the clever method of consuming the oil without previously converting it into a fixed gas.

This will be better understood when I mention that in the largest engines only the $\frac{1}{250}$ part of a pint of this high test oil is used at any one time, and in the smallest sizes the fuel is prepared in correct quantities varying from $\frac{1}{7000}$ of a pint upwards, according to whether the engine is running on light or full duty. I think this fact alone demonstrates to a remarkable degree how wonderfully accurate are the system and devices which have been patiently worked out in the Priestman engine to have resulted in it obtaining a good name for itself, as it has done, in unskilled hands and for such a variety of uses. Of course, in gas, gasoline or naphtha engines, the gas has only to be taken into the engine in the right quantity, but in this case the working agent being heavy oil, each charge must be first carefully prepared.

Not very long ago, a lecture was delivered in this hall on "The Compressed Air of the Future," by Mr. Wm. L. Saunders, calling your attention to the wasteful method of using compressed air as a motive-power, and in the beginning of his lecture he stated that compressed air for motive-power purposes, was not necessarily air that had been compressed by mechanical means, but that air at atmospheric pressure confined in a close vessel and sufficiently heated would indicate upon a pressure gauge an expansive force according to the amount of heat imparted to that air. If air is compressed mechanically heat is developed and the heat manifested is in proportion to the amount of compression. Heat applied to confined air results in expansion and pressure so that if heat is applied, say internally, to confined air expansive force is developed without mechanical compression.

If you will take the trouble to read in the *Franklin Institute Journal* the report of that lecture, and compare it with what I will show you this evening, you will, I think, come to the conclusion that this engine is not actuated by petroleum, but that it is properly an air engine using petroleum as fuel, on the correct principle of application of the heat with the least loss.

In the present case the function of the oil is to heat and expand the air, and as you will presently see, the method of controlling the power of the engine or governing its speed, is by varying the amount of fuel burned and the amount of air that is heated by each regulated charge of fuel and air. This is a case precisely analogous to that of a hypothetical steam engine which receives steam from a boiler fitted with all modern automatic contrivances, whereby the amount of combustion is regulated by the work to be done, so that the amount and pressure of steam generated may be varied each moment to suit the force required; but, with this important distinction that in the Priestman engine are avoided the danger and complications arising from low water, dirty water, foaming boiler, leaky joints and all other incidents attending the operation of converting water into steam and conveying it to the engine.

The Priestman engine uses for fuel common petroleum such as is burned in lamps, and the quality best suited to this purpose is just what is safest in common use; that is, the highest proof oil. This oil is ignited in combination with air under a low pressure, created by the return stroke of the piston. Some part of this air supports the combustion of the oil, and the heat generated by the combustion of the oil expands the air that remains and the products resulting from the explosion, and thus develops its power from air that it takes in while running. In other words, the engine exerts its power by inhaling air, heating that air and expelling the products of combustion when done with.

You all know that high-proof oil is not highly inflammable, and to bring this fact clearly before your minds, I have in these two porcelain dishes, two petroleum products; in one some of the oil commonly used in the Priestman engine; in the other some of the lighter products of petroleum equivalent to what is employed in the naptha engines. In the case of the oil, a lighted taper presented to its surface shows no indication of ignition and in point of fact the taper can be extinguished readily by immersing it in the fluid oil if the vessel was deep enough. In the other case, a lighted taper brought to the locality, the whole mass bursts into flame from the ignition of the inflammable vapors that are continually escaping from all these lighter hydrocarbons.

When oil is burned in a lamp it does not necessarily ignite very quickly when the match is applied to the wick. The full intensity of the light, in fact, is not given off by a lamp until the wick and adjacent parts are sufficiently heated to cause a rapid evaporization of the petroleum that is drawn up in the wick by capillary attraction. When heated, the gas will burn more actively than when cold. Coal or wood must also be heated up to a certain extent before either will ignite, but when coal is finely pulverized, made into a powder or dust and mixed with air, it will ignite much more readily than when in a large mass, and one of the methods of using coal for fuel quite successfully, tried in some instances, is to pulverize the coal and discharge it in dust form mixed with air into the furnaces where it burns actively in the same manner that oil divided minutely by an atomizer will burn when the same oil will not burn in a solid stream projected into or through the flame of a lighted lamp.

I can show you the action of the atomizer that is used in the Priestman engine to reduce the oil that is required for fuel into the form of dust that it may more readily be ignited, by means of the piece of apparatus which is used in testing certain parts of each engine and chiefly in adjusting the spray-maker.

I ought here to state that a very valuable feature of this atomizer is, that it is constructed so that its adjustment is not alterable or necessary to be altered in the hands of users.

By pumping air into the chamber containing oil, it will press on the surface of the oil contained in the chamber, and a fine stream of oil, driven out by the air pressure, can be thrown from the nozzle, and you will observe that holding a lighted candle to this jet, not only does not ignite it, but it may extinguish the flame of the candle. We now have attached to the same nozzle, the device used in the engine for converting this stream of oil into finely divided particles, mixing these particles with air. The ejected oil ceases to be a solid stream, it is broken up by the counter-current air and there is a mingled spray expelled from the apparatus; in fact, a cloud of oil dust. Approach a light to this spray and it instantly ignites and burns with a roaring flame.

This spray formed by the current of compressed air conveyed by a pipe from the air space in the oil tank is not a gas. This can readily be proved by means of a small bottle with an opening in the side besides the usual neck of the bottle. Presenting this side opening to the spray-maker, so as to catch the out-coming air and oil dust, the oil is caught in the bottle and the air separating from the spray passes out through the neck of the bottle. You can readily see the action of the oil falling to the bottom of the bottle, while a taper applied to the neck where the air is escaping does not ignite the air that escapes separate from the oil. This shows that the spray is merely a mechanical mixture of oil and air, each liable to separate from the other if they are given time to come to rest.

If we were to attempt to introduce this spray into the cylinder of the engine and there ignite it, we should find that the oil had passed back into the condition of solid oil, just as is done in the bottle, and ignition could not be effected by the electric spark. To prove this to be the case, I will ignite the vapor by the same kind of spark from the same battery that is used with the engine to ignite the charge at each stroke. The spark ignites the spray while mixed with the air, but the same kind of spark applied to the air escaping from the bottle, as in the former experiment, produces no ignition whatever, nor will this same spark applied under the oil surface ignite the oil in its fluid condition.

To insure the divided oil and air, mixed in the proper proportion, to remain long enough mixed, it is necessary that it should be moderately heated. To start the engine the mixer used in connection with the cylinder is warmed by the flame of a lamp, using oil dust and air in form of spray, to enable the first charge to be ignited, after which the heated products of combustion escaping from the cylinder are utilized to keep this chamber to its required temperature, without which heat the oil would drop away from the air, as it did in the bottle, as soon as it enters the cylinder.

Professor Unwin, in his paper, enumerates some of the many attempts to use hydrocarbon oils internally in engines, the invention of some of these processes dating back nearly fifty years, and he shows why the complex constitution of the oil gave rise to practical difficulties.* In converting these oils into vapors, to be introduced into an engine, the high heating and the resolution of the oil into stable gas, left certain tarry products behind that clogged the machinery. Priestman, by using the oil as oil dust in a warm condition, is able to burn that oil precisely as it would be burned in the wick of an oil lamp, and his aim is to burn all the oil, except that in contact with the cooler surfaces of the water-jacketed cylinder. Upon these cooler surfaces, the oil not burned is condensed and furnishes the means of lubrication without clogging the working parts by the formation of any tarry product. Some time ago I was cognizant of a remarkable demonstration of this fact. I had an opportunity to examine one of these engines after a five and a half weeks' run, and after 2,500,000 explosions had taken place in the cylinder. This engine, when taken apart, showed no perceptible injurious deposit on any part of the inside of the cylinder or in any part that was examined. There was nothing to indicate that oil had been used in it, except the clean well-oiled condition of the cylinder itself. The ignition plug had not even once been removed during this run and the platinum points were as clean as when put in.

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* See p. 7, Unwin on *Petroleum Engines.*

In engines of this class, there is a space back of the cylinder, over which the piston does not sweep in its motion. This space is a small reservoir, bearing a fixed proportional relation to the whole cubical contents of the cylinder. This space acts as the furnace and boiler that is to operate the engine, and in point of fact is the seat of power of the machine.

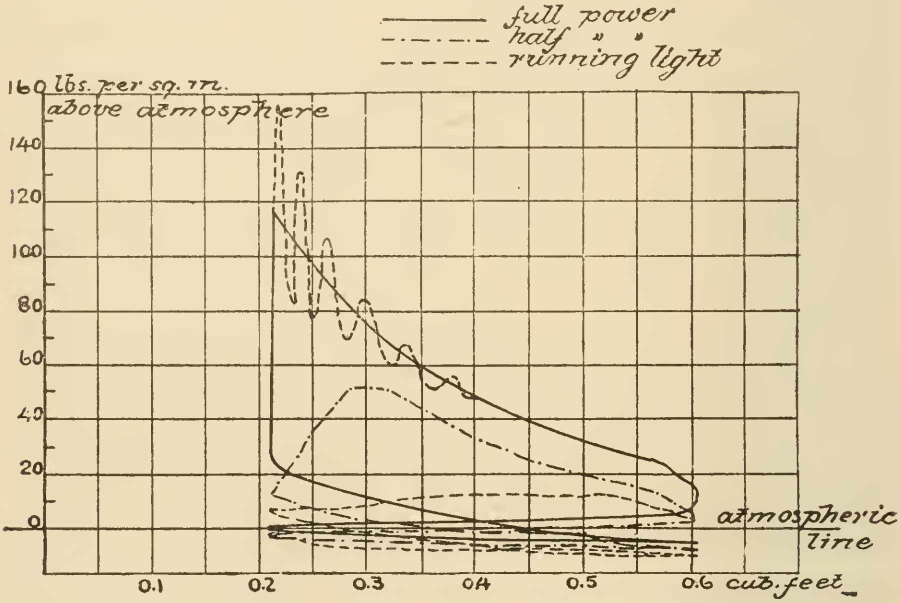


FIG. 3.

The Priestman engine is of the single acting, bi-revolution type ordinary in heat engines. One explosion takes place in each two revolutions of the crank. A charge of air and oil dust, moderately heated, is discharged into the cylinder during the forward motion of the piston, on the return stroke this charge is compressed to less than half its bulk, and explodes while the crank is on its dead centre. The result is an expansion of air and products of combustion, and these act continuously afterwards at a decreasing pressure during the full forward stroke (*Fig. 3*), and when at the end of that forward stroke, the exhaust valve opens, allowing what remains to escape, and the products of combustion that have not escaped are expelled or swept out by the return stroke of the piston, completing in this way one full cycle. There is a small pressure on the oil tank, sufficient to enable the air to be forced from the cold oil tank, the air from this reservoir, charged with oil dust, passing through the mixer, takes up its due proportion of heat, as does also the free air drawn in at the air valves, expands somewhat from the heat imparted to it, a charge enters the cylinder, is compressed and ignited, expanding and thus giving the force required.

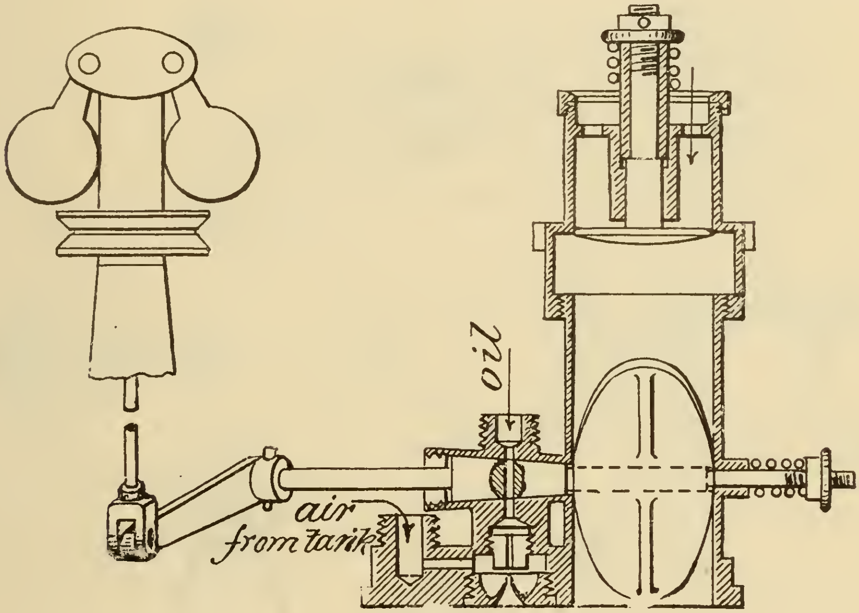


FIG. 4.

The spraying nozzle as now used (*Fig. 4*), and to be explained to you, pulverizes or tears up the oil into very fine atoms, and at the same time protects the mouths of the passages from deposits of carbon which would choke and alter the character of the spray and affect the quantities of the oil and air. It will readily be appreciated that the difficulties which I have mentioned, and which have so long stood in the way of successful kerosene engines, were not overcome until after numerous trials had been made by Priestman, extending over a period of some years, and which have resulted in a process which, as Professor Unwin correctly states, is "very ingenious and worked out with great scientific skill."

The form of this nozzle was gradually changed. The earliest form, consisting simply of a concentric conoidal mouth-piece, the near or oil mouth-piece being ended in a fine point. After some time it was found better to make the oil nozzle blunt so that the air was turned at a right angle at the moment of issue, and lastly the form of the air mouth-piece is re-entrant, and the air turns through an angle greater than a right angle at the point of issue of the oil jet.

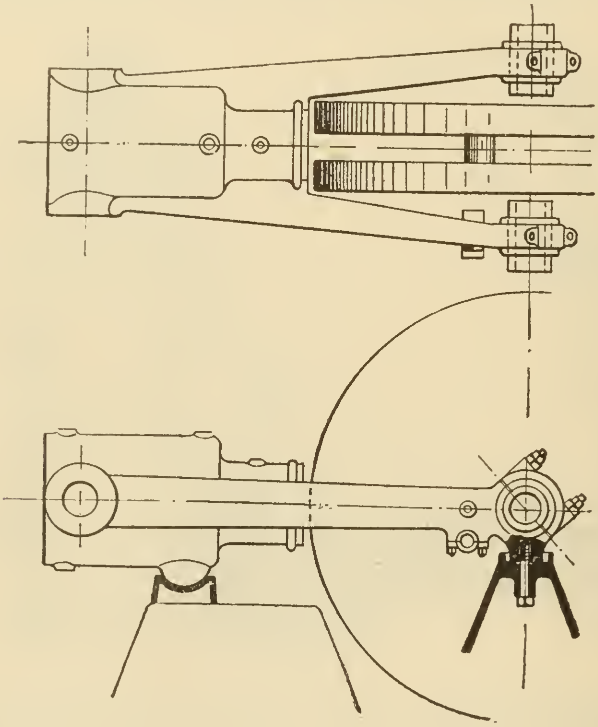


FIG. 5.

In the first of these, the oil is forced into and through an escaping column of air. Gradually the nozzles were shortened, and changes made to make the union a much more violent action until finally the air nozzle was turned back towards the oil nozzle, so that the current of air within the nozzle turned towards the escaping stream of oil. In other words, the air is actually blown in against the escaping oil, and the two thus brought into violent conflict are driven out into a spray of the required condition.

The regulation of the engine by governor to effect the variation of power called for by varying demands, is effected by varying the oil supply and not, as is the case in most gas engines, by suppressing some of the explosions. The spindle which regulates the feed of the oil in the spray-maker also regulates the supplementary air by means of a wing valve.

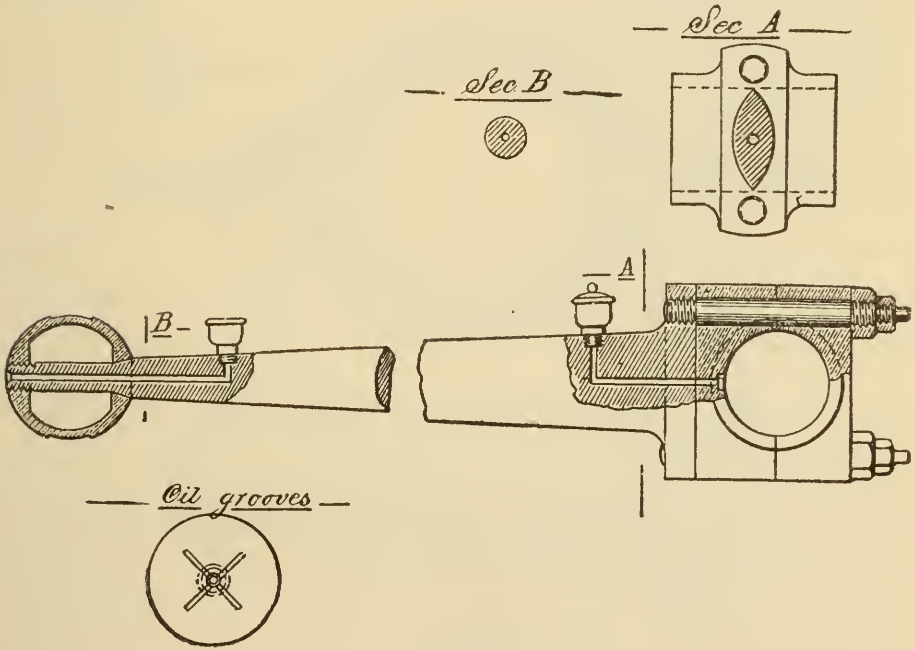


Fig. 6.

In general appearance the engine will at once be recognized as modelled on the straight line principle.

The foundation plate (*Fig. 5*) acts the part only so far as forming a support, but advantage is taken of the rear support by making it large enough to serve as a convenient oil tank, holding a supply for from fifteen to twenty hours full load.

The cylinder and frame (*Fig. 5*) are cast in one piece, the cylinder being water jacketed, the arms hollow of box section. These arms carry the main bearing boxes. Near the back end of the cylinder are ports for the reception of the inlet and exhaust valve boxes. The cylinder and frame rests on three points, so that there can be no warping due to settling of foundations, and two bolts are used to secure the frame directly under the main bearings, while the cylinder end of the engine rests on the oil tank in a spherical seat, thus allowing free expansion and contraction.

The crank and fly wheel are precisely the same as in the straight line steam engine, and are peculiarly well adapted to this class of engine, as the shock due to explosion is almost entirely absorbed by the wheels, thus taking the wear off the main bearings. As a proof of the perfection of this action, in an engine of eight actual horse-power running daily for over a year, there is not the slightest evidence of any wear having taken place; the grinding marks are still in the shafts and the scraping marks in the babbitt.

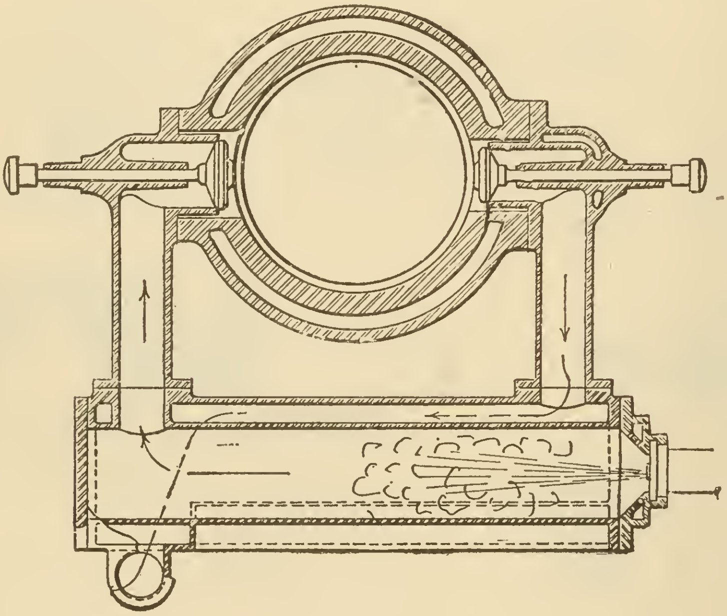


Fig. 7.

The connecting rod (*Fig. 6*) is a steel casting fitted with cast-steel boxes babbitted. It is attached to the pi[illegible] by a ball joint.

The inlet and exhaust valves (*Fig. 7*) are placed opposite each other near the back end of the cylinder. These are cast-iron poppett valves with cast-iron seat and steel stems of sufficient length to withstand the wear and at the same time remain air-tight with packing or glands.

ERRATUM.

Page 106, last line, for "with" *read* "without."

The exhaust valve is water-jacketed and operated positively by a cam (*Fig. 8*). The inlet valve is opened automatically by the suction of the piston.

The mixer (*Fig. 7*) is a cast-iron jacketed cylinder, around which the exhaust products are allowed to pass, keeping the inner chamber, into which the oil dust and air are ejected at a sufficient heat to prevent condensation of the oil dust.

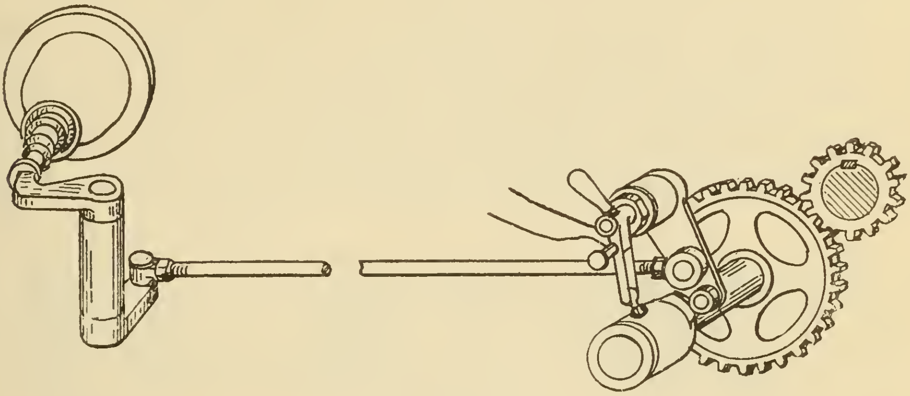


Fig. 8.

The mixer is swung by connecting pipes from the inlet and exhaust valve boxes.

The air pump (*Fig. 9*) consists of a plunger turned to a proper working fit in the barrel without packing. The flap valves are rubber discs, which act noiselessly. The suction valve is provided with a strainer, made of two pieces of perforated brass, with a layer of cotton wool between them, to prevent any dust or grit passing into the oil tank.

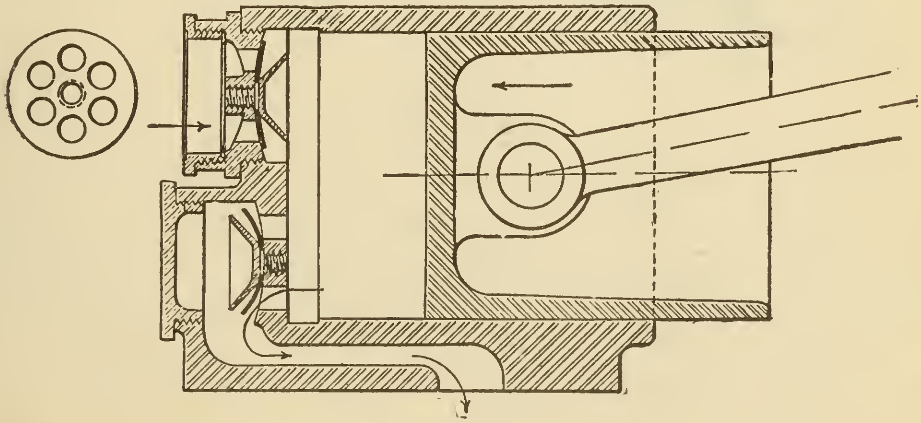


Fig. 9.

A smaller pump arranged for operation by hand is provided to get up the necessary air pressure for the heater lamp in starting the engine.

The ignition device (*Fig. 10*) consists of either a primary or storage cell and induction coil. The primary wires are attached to a brass fork, the contact being made by a brass ball passing between the fingers at the proper moment. The secondary wires are connected to the ignition plug. This plug is made of brass, the wires in passing through it are insulated by two pieces of porcelain, and are provided with platinum points, between which the spark plays.

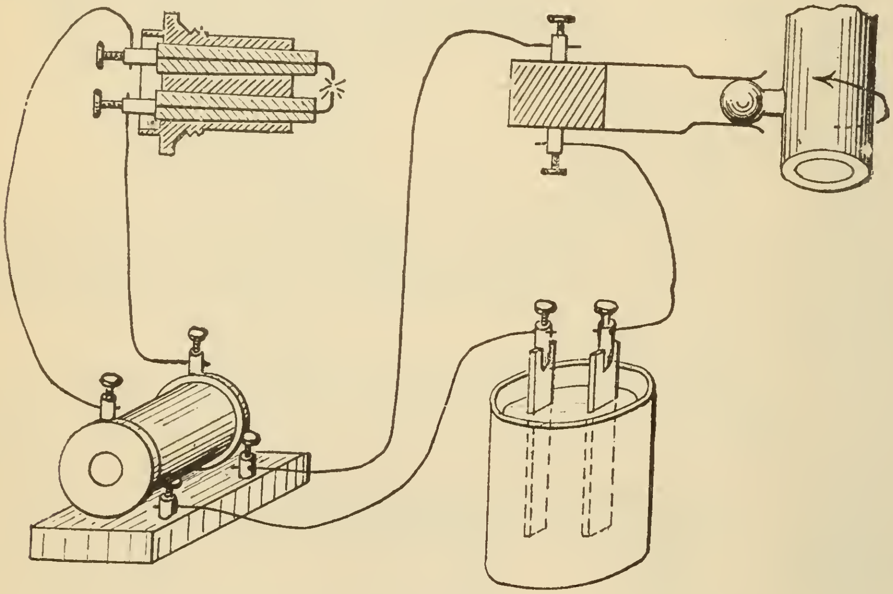


FIG. 10.

Having pointed out to you the main features of this new prime mover, it only now remains for me to show you that the Priestman engine, although its manufacture in Philadelphia has so far been more of a preliminary character, has nevertheless in various classes of uses in this country, procured itself in actual daily practice, and in unskilled hands, to be entitled to the claims in its favor, which I have to-night put before you, or in other words, that it has in this country, and in its new form maintained that good record testified to by Professor Unwin, Lord Kelvin and many others in England and elsewhere.

The Philadelphia Fire Underwriters' Association have had a full explanation of the functions and mode of operation of this petroleum engine, and have approved its use without any increase whatever in the rate of insurance.

When one of these engines was exhibited at the American Institute Fair the objection that had been held by Underwriters to oil engines in general influenced the managers of the fair to enter objection to the running of this engine in the exhibition until it was proved to their satisfaction that no gas was generated in the process of operating it before ignition, and that there was no danger either from explosion or from the escape of inflammable gas through leaks or otherwise.

With your permission, I therefore propose to read to you a few letters I have lately received from users of the engine in different classes of work:

For Electric Lighting.—Prof. Elihu Thomson writes me:

(Copy.)

THOMSON-HOUSTON ELECTRIC COMPANY.

THOMSON ELECTRIC WELDING COMPANY.

OFFICE OF ELIHU THOMSON.
LYNN, Mass., October 26, 1892.

Dr. Coleman Sellers, 3301 Baring Street, Philadelphia.

MY DEAR SIR:—Yours of the 20th inst. has been received.

I can say in reply to your inquiry that I consider the Priestman oil engine a very convenient engine to run, and that it at the same time gives power at a low cost. I have not made any direct tests of its efficiency so as to state the percentage. The only trouble we have ever had with it has been on one or two occasions when there was a failure of the piston to lubricate itself properly, but I think we will get over that difficulty altogether by mixing our oil, which is the regular 150° test kerosene, with a heavier oil, or one containing paraffines having a very high boiling point. This will adhere to the sides of the cylinder and piston and not be vaporized therefrom by the heat.

I certainly think the engine is a great step in advance of the utilization of comparatively cheap fuels in a scientific manner for obtaining power.

I am using pure silver in place of platinum, not at the igniter electrodes but for the vibrator contacts on the induction coil. It is our experience that pure silver makes a contact which can be relied on to work without getting blackened or coated with a non-conducting substance, such as forms in the case of such metals as platinum. The fact is a slight spark volatilizes a portion of the platinum contacts of the vibrator which condenses as platinum black between them, and in a moderate time destroys the contact, demanding that a cleaning operation be resorted to. We have run our silver contacts for several weeks without cleaning, and the regularity of action is as perfect as could be desired.

The use of gas for starting we find a very great convenience, as it does away with the flame and smoke in the room when the mixer is allowed to heat up by the oil, and, furthermore, enables us to put on the load of the engine within two or three minutes after starting. We keep the gas on in moderate amount until the mixer is heated up to such a point that the engine can run with the oil alone. We find that it takes about twenty-five cubic feet of gas, as measured by the meter. I think I will be able to reduce this amount considerably by some little changes I am making.

There was, of course, the possibility of the governor of the engine sticking or the belt breaking or coming off, which might allow the engine to run away, and as it was my intention to start the engine and allow it to go with practically no attention during the run, I provided a little switch in the battery circuit, which switch is clamped to one of the bearings of the engine, and there is a small centrifugal device, which on a speed of 260 to 270 being reached will be thrown out and knock the switch open, thus cutting off the igniting current. I have caused the engine to run away on two or three occasions and tested the device. It works perfectly.

I suppose that you have been told by Mr. Priestman that our exhaust pipe is led underground in a mass of loose stone, and that on testing the engine with the free exhaust we find that it carries just the same load as it does when the exhaust is underground. The back pressure is insignificant, owing probably to the fact that our pit was carried into a loose gravel bank, which bank is many feet above water level, and forms practically, therefore, a sort of air sieve into which gases can be discharged with comparative freedom from back pressure. This rids us of the smell and noise of the exhaust.

We have not yet put in our storage batteries and are running the engine and dynamo directly for lighting. We run about five hours each evening and have been starting up the engine and leaving it running in the dark for hours together while supplying the light to the house. We can say, therefore, that outside of the starting and stopping it demands practically no attention and is automatic in all respects.

For cooling the cylinder we simply have a large tank in the attic of our building connected by two pipes, one at the top of the cylinder and the other at the bottom, and this gives us a vigorous water circulation, and at the same time secures for us a supply of warm water which can be used during the winter in the stable.

I may have transcended the limit of your inquiry, but I felt justified in doing so from the desire to have you know more fully than a mere statement of the convenience of the engine would give, how useful and valuable it is. If there are any points concerning it about which I can give you any further information I should be very happy to do so. I am,

Very truly yours,

[SIGNED] ELIHU THOMSON.

For Pumping.—Mr. Coxe writes me:

(Copy.)

CROSS CREEK COLLIERIES, COXE BROS. & CO.

DRIFTON P. O., LUZERNE CO., Pa., October 25, 1892.

Coleman Sellers, Esq., 3301 Baring Street, Philadelphia, Pa.

DEAR SIR:—Your letter is received.

We have had the Priestman oil engine working in our No. 1 Mine, at Drifton, for nine months. It was put in the mine on February 1st, and ran nicely until February 20th, when we had some trouble caused by the gas failing to ignite properly. At our request the Priestman Company sent a man to examine it. He came on the 26th of February and found the oil passage to governor blocked with soot and some fine particles in the valve of the air pump. From this time until March 14th it ran very well, but from this time until the middle of April we had considerable trouble to keep the oil pipe open, and the spray-maker would continually block with soot or lamp-black, and the engine would run only for a short time, one hour or less, and at last it got so that it would not run at all. We took out the piston and found the piston rings and the back of cylinder entirely blocked with soot. After we had cleaned these, we put them back and started up again. We ran for about a week, and then experienced the same trouble as before. We took it apart and cleaned the piston rings and back of cylinder as well as the oil pipe and spray-maker. The engine then started off and ran very well. At this time we got the water down so as to open the air shaft of the mine, thereby giving us plenty of air to work the pump, and from that time to this we have had no trouble; except about one week ago, when, in consequence of a change being made in the air course in the mine, we had trouble for a short time. We are satisfied that had the pump had a full supply of air from the start we would have had no trouble.

It seems to us that this is an important point to remember when putting a pump into a confined place where it may exhaust into the same atmosphere in which it works (of course, this could not occur in an open space). As the pump is adjusted to do its work with a supply of normal air, when the quantity of oxygen is decreased and the quantity of carbonic acid is increased, perfect combustion cannot take place. Some of the particles of carbon in the oil being unconsumed, deposit themselves as soot or lamp-black in the various parts of the engine. In our case, in consequence of the water having been pumped out, the bottom of the air shaft (which was closed by the water) was opened and a good current of air was established when the whole difficulty disappeared. For the last five months, except when we were changing the air passage in the mine a week ago, the engine has worked very satisfactorily.

The engine seems to run very well when the air supply is pure, but when the air is not pure you may have trouble. This, of course, does not apply to an engine placed outside.

The engine we have is pumping water. It is connected by means of a friction clutch to a pinion which gears into a large wheel; on the shaft of the large wheel, there is a small pinion which gears into another large wheel on which is a crank which drives the pump.

It is very important to have good supply of fresh air to the pump, as we find that in every case where our ventilation is for any reason defective, the pump shows it at once.

We do not run the pump steadily as it depends upon the amount of water that the mine is making. When running steady we use from four to five quarts* of kerosene per hour. It was a twelve-inch cylinder and twenty-four-inch stroke and raises the water a little less than ninety feet. Our object in getting the engine was to have a pump that we could move about, as the workings would gradually deepen and extend, and the pump could not always be kept in the same place. For this class of work we find it very satisfactory.

I enclose you a blue print of the exact arragements.

Hoping this will give you the desired information, I am,

Yours truly,

[SIGNED] ECKLEY B. COXE.

For Cotton Ginning.—Mr. M. Wilkins writes me:

(Copy.)

FAUNSDALE, MARENGO CO., Ala., December 5, 1892.

Dr. Coleman Sellers, Philadelphia, Pa.;

DEAR SIR:—Your favor of November 30th to hand this day, and in giving you my experience with the Priestman engine, will say I have used it to drive my cotton gin, gin feeder, condenser and cleaner, and find it superior to any power I have seen for this purpose.

In ginning we need a very steady, smooth power, as some parts of our machinery are driven at a high rate of speed, and any jerking or racing injures the fibre as well as the machines. Its fine governing qualities fill another emergency for us, in enabling us to throw the load off at any time with impunity, as sometimes we find sticks, stones, pieces of iron and the like amongst our gin saws, which requires an instant stopping of the gin.

I had occasion to test it severely a few days since, finding a bonnet lost by one of my pickers had gotten tangled in the gin feeder, while the engine (alone down-stairs) was driving a very heavy load, I threw the clutch pulley out in a second and rushed down-stairs to see the result. I soon found out the gin needed my attention, as the engine was taking care of itself splendidly.

The igniting device I find absolutely perfect, having never failed in a single instance when properly adjusted. I was instructed by the builders to carry the exhaust about twenty or thirty feet up, but not being convenient to do so, I put it out laterally about three feet from ground level, and have experienced no trouble at all from disagreeable smell.

---

* This is a nine effective horse-power engine.

Having no stream to depend upon for water to circulate around the cylinder, I mounted twenty barrels and connected them with one-inch nipples six inches long, which gives me enough water to make a steady ten hours' run, and by next morning water is all cold again.

I have experienced no trouble in regard to the piston which I feared would not lubricate as it should, also find the bearings in good shape after as long as six hours' runs, showing the lubricating arrangement in that line was perfect.

My pump let down once but I found I was drawing out of the barrels without a screen over the suction pipe and a small chip got in the pump valve, which I removed and had no further trouble. By adjusting the thumb screw on the relief valve I have regulated the air pressure on the oil tank to a nicety.

I have never figured accurately on consumption of oil, but don't think I have ever used over one pint per hour to the horse-power, if that. I am so pleased at the idea of being rid of the treacherous steam boiler and the expensive handling of wood or coal to keep up steam that I am very willing to allow the engine one quart per hour.

I usually heat the mixer about twenty minutes, start the engine and let it make about a dozen revolutions then throw on the load, and leave it.

I handle my engine with ordinary field hands who never had any experience with other motors than hay burners (mules) and think I have a simple, safe, economical and reliable power.

I may have somewhat over-reached the limit of your request but trust the humble opinion I have expressed may cause others to take hold of the Priestman engine, and be as much pleased with it as I am. If I can be of any further service I am yours to command.

Your obedient servant,

[SIGNED] M. WILKINS.

MANGANESE STEEL.

By Henry M. Howe.

[*A lecture delivered before the Franklin Institute, February 20, 1892.*]

Mr. Howe was introduced by the Secretary of the Institute, and spoke as follows:

Members of the Institute, Ladies and Gentlemen:

Manganese steel is an alloy of iron with from say three to twenty per cent. of manganese. Certain varieties of it are extremely ductile, and yet very strong and extremely and unchangeably hard. This combination of simultaneous hardness and ductility is, I believe, quite unique.

Common or carbon steel may be extremely ductile in its annealed state, and extremely hard in its hardened state; while the self-hardening steels are nearly unchangeably hard, but always brittle. I know of no substance, organic or inorganic, except manganese steel, which is at one and the same time both hard and ductile. Indeed, hardness and brittleness usually go hand-in-hand to such a degree that the word "hard" is often carelessly used in the sense of "brittle." And I believe that not a few of us have, by association, come to regard hardness and ductility as in some way absolutely incompatible.

Manganese steel was discovered and patented by Robert Hadfield, and to him and his son we owe most of our information about it.

Manganese steel conducts both heat and electricity extremely badly, and is but faintly magnetizable.

The influence of manganese on the properties of the alloy is probably profoundly influenced by that of the carbon, which at present unavoidably increases with the manganese. We cannot now make thirteen per cent. manganese steel with much less than one per cent. of carbon; and we can only guess what its properties would be without this carbon.

Let us consider some of the properties to which I have thus referred, and later the preparation and the uses, actual and anticipated, of this remarkable material.

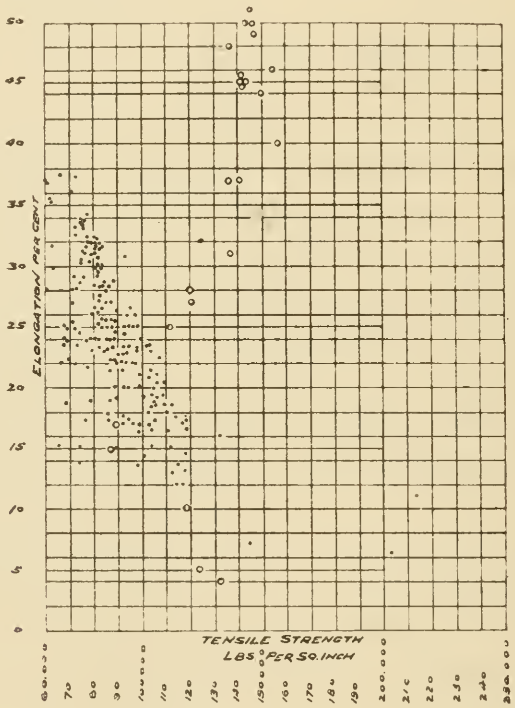
Its properties vary strikingly with the proportion of manganese which it contains, and with the treatment it has undergone. Except where the contrary is explicitly stated, I confine myself to-night to the alloy containing about thirteen per cent. of manganese, in its ductile or "water-toughened" state.

Let us first consider the tensile properties of manganese steel, its tensile strength, both elastic and ultimate, and the ductility which a bar of it displays when torn apart longitudinally or tensilely, as in the most common form of tests for engineering and scientific purposes. The general worth or merit of any particular lot of iron or steel is usually measured by its combination of strength with ductility. I do not now speak of its fitness for this or that particular purpose, but of its general merit. The scientific investigator needs one set of qualities; the poet, a second; the statesman, a third. Nevertheless, there are common standards which we apply to all, as measuring their general merit as men.

In case of carbon steel, at one extreme we have metal of enormous strength, but so brittle and treacherous that the engineer dare not use it. At the other, we have metal of extraordinary ductility, but so weak as to be of little value for many purposes. So, in a rough way, we habitually regard that steel which has the greatest strength for given ductility, or that which is the most ductile for given strength, as the best.

The most common measure of ductility is the permanent elongation which a bar of the metal undergoes when it is pulled in two by direct longitudinal stress; and this elongation is habitually measured in percentages of the initial length of the bar tested. The combination, then, of tensile strength with the permanent elongation on tensile rupture, or in short of strength and elongation, is the standard by which I first ask you to judge the excellence of manganese steel.

In *Fig. 1*, I have represented this combination graphically for manganese steel, and for many of the best reported specimens of common or carbon steel. (To distinguish common steel from manganese steel, I shall speak of it in this lecture as carbon steel.) In this diagram the ordinates, or the vertical distances of the several spots from the horizontal axis, indicate the ductility as measured by the permanent elongation undergone by a given test-piece prior to rupture; the abscissæ, *i. e.*, the horizontal distances of the several spots from the vertical axis, indicate tensile strength. The little black spots represent the properties of carbon steel, and you note that they fall in a tolerably well-defined band, the elongation diminishing as the tensile strength increases.



TENSILE PROPERTIES OF CARBON-STEEL
AND OF MANGANESE-STEEL.

○ = Water-toughened Manganese-Steel
• = Carbon-Steel.

FIG. 1.

Note, however, how greatly the manganese steel specimens excel those of carbon steel in their combination of strength with ductility. For a tensile strength of from 130,000 to 150,000 pounds per square inch, none of the carbon steels have more than sixteen per cent. of elongation; while many of the manganese steels of this strength have an elongation of forty-five per cent., and some even of fifty per cent.*

But I think that this combination, which we have been considering, ultimate strength with ductility, is by no means so good a measure of general merit as the combination of ductility with elastic strength, or tensile strength within the limit of elasticity, or, as it is called, elastic limit. The elastic limit measures the power of the metal to resist stress without becoming permanently deformed. It is this, probably, rather than the ultimate tensile strength, that should, and some day will, determine the stress to which the material shall be exposed in practice. The ultimate strength of the material measures the stress, a single brief application of which will tear it apart; the elastic strength or elastic limit seems to measure the stress which, if indefinitely prolonged or repeated, will tear it apart. Now, if this be true, no matter how great the ultimate strength, we should not dare to expose materials indefinitely to a stress as great as their elastic limit.

Therefore, in *Fig. 2*, I have in like manner represented the combination of elastic limit with elongation in case of carbon steel, of manganese steel and of nickel steel. The little spots for carbon steel as before fall in a band running obliquely across the diagram, less clearly defined because of the smaller number of cases.

Two of the triangles, indicating nickel steel, lie well above the band of carbon steel; but even these are excelled by many of the circles which stand for manganese steel. [Since this lecture was read, other tests of nickel steel have come to my notice, in which this combination is as great as it is in the cases of manganese steel represented in *Fig. 2*.]

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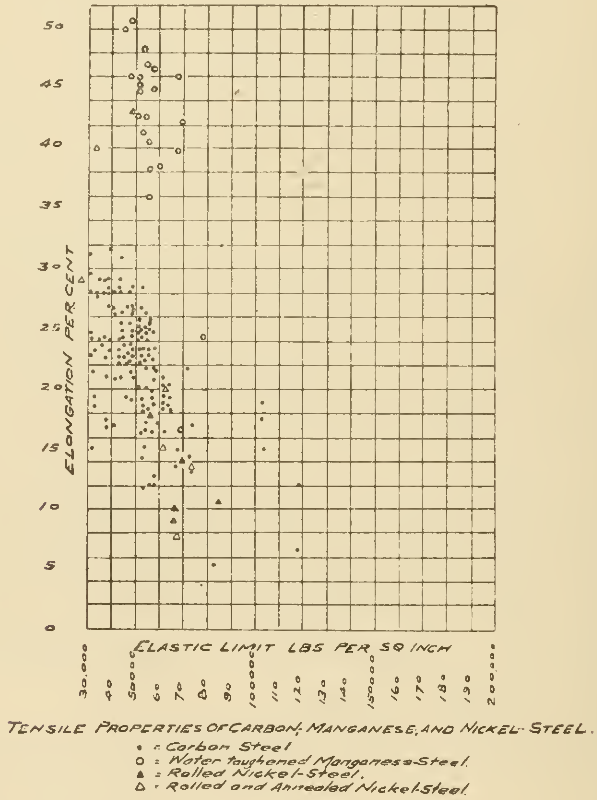
*Since this lecture was delivered still more extraordinary combinations of strength and ductility in case of manganese steel have been reported. Mr. E. G. Spilsbury found in case of one specimen of wire a tensile strength of 400,000 pounds per square inch, with an elongation of thirty-three per cent. in six inches. An extraordinary case of ductility is reported by the same gentleman. Wire of No. 18 gauge, 0·046 inch in diameter, endured forty-eight twists in a length of six inches, and twenty-two bends. Its tensile strength was 155,000 pounds per square inch, and its elongation seventeen per cent. in six inches. These are picked results: in the first of them, an error is possible, though extremely improbable.

These comparisons may, however, give a false idea of the ductility of manganese steel. If two metals elongate in a like manner, the extent of their elongation may be a fair comparative measure of their ductility; not necessarily so, however, when their mode of elongating is unlike in kind. A bar of carbon steel habitually yields when pulled in two by "necking," contracting greatly just about the place where rupture occurs, as shown in *Fig. 3*, while a bar of manganese steel or of brass elongates far more uniformily over its whole length. For some purposes this uniform stretch may be better, for others worse, than the necking and localized stretch of carbon steel; suffice it here to point out that the two are different, and, therefore, not strictly comparable as a measure of ductility: and further that, thanks to the nearly uniform stretch of manganese steel over



TENSILE PROPERTIES OF CARBON, MANGANESE, AND NICKEL-STEEL.

FIG. 2.

the whole length of the test bar, its percentage of elongation may be held to give an exaggerated idea of the metal's true ductility or plasticity.

This granted, it yet remains that the metal is very ductile and has great strength, both elastic and ultimate.

This leads me to speak of a further peculiarity of the ductility of manganese steel, the difficulty with which cracks are propagated across it, *i. e.*, its non-fissility. This is illustrated by *Fig. 4*, in which are sketched the condition of one and the same test bar of manganese steel, in different stages of elongation under tensile stress. The stretching was interrupted several times, and each time the test bar was water-toughened, *i. e.*, was heated to redness and then plunged in water. You will note, first, the uniform stretch over the whole length of the test-piece, in marked contrast to the necking of carbon steel shown in *Fig. 3*. Next you will notice three rough diamond-shaped figures in each of the lower three sketches. These are deep holes, unexpectedly resulting from the stretching of very light prick-punch marks; one of them is more than one-sixteenth inch deep, and one-fourth inch across. That so hard a material should tear in this way is most surprising. In one case daylight could be seen

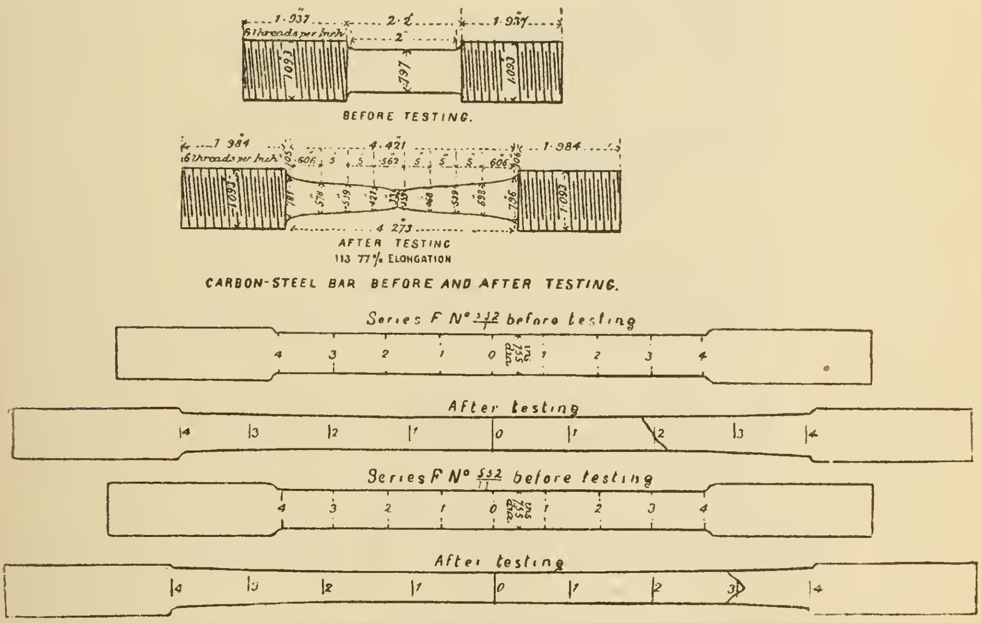


FIG. 3.—Manganese steel bar before and after tensile test.

through a test-bar while it was still enduring a tensile stress of over 110,000 pounds per square inch.

So in testing manganese-steel knuckles for automatic car-couplers, by an impact or drop test, it has been noted that, after the metal has begun to crack, it endures a surprising number of blows before breaking.

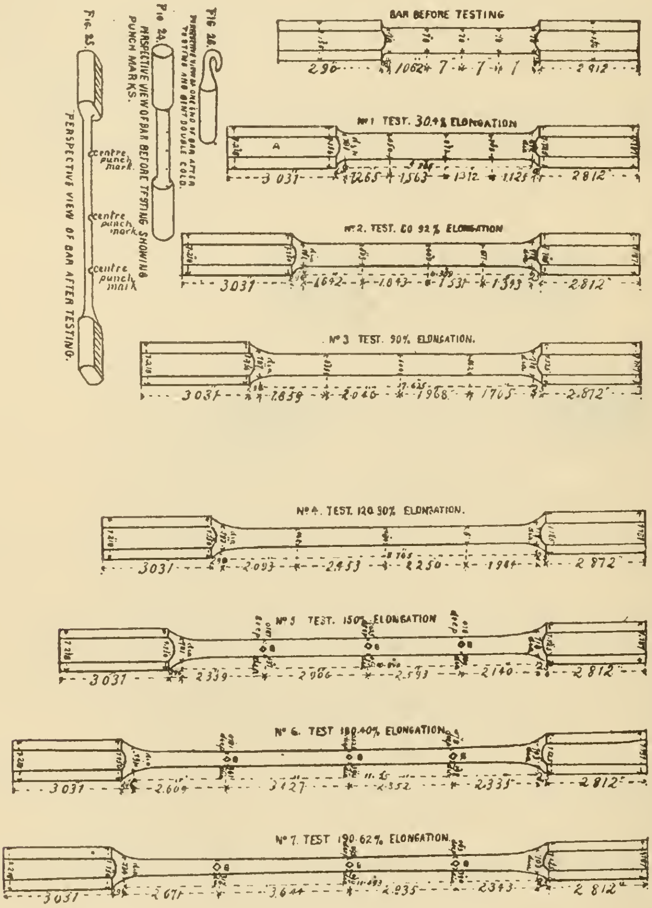
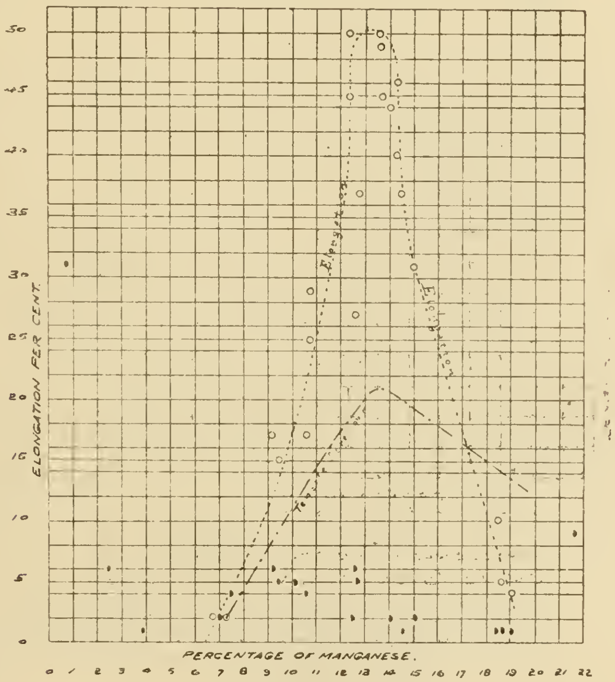

BAR BEFORE TESTING
2.90
1062
7
7
1
2.912
No 1 TEST. 30.4% ELONGATION
A
3 031
1265
1563
1312
1125
2812
No 2. TEST. 60 92% ELONGATION
3031
1642
1.843
1.531
1.513
2.812
No 3 TEST. 90% ELONGATION.
3031
1.659
2.040
1968
1705
2.872
No 4. TEST. 120.90% ELONGATION.
3031
2.093
2.453
2.250
1.984
2.872
No 5 TEST. 150% ELONGATION
3031
2.339
2.966
2.593
2.140
2.812
No 6. TEST 180.40% ELONGATION
3031
2.604
3.127
2.352
2.335
2.812
No 7. TEST 190.62% ELONGATION
3031
2.671
3.644
2.935
2.343
2.812
FIG 25.
PERSPECTIVE VIEW OF BAR AFTER TESTING.
centre punch mark.
centre punch mark.
centre punch mark
FIG 24.
PERSPECTIVE VIEW OF BAR BEFORE TESTING SHOWING PUNCH MARKS.
FIG 26.
PERSPECTIVE VIEW OF ONE END OF BAR AFTER TESTING AND BENT DOUBLE COLD.

FIG. 4. Appearance of a single test-bar of manganese steel, before and after repeated stretching, each followed by water-toughening.

The way in which the tensile strength, and more especially the ductility of manganese steel, vary as the percentage of manganese increases, is very striking. As the manganese rises, the ductility at first diminishes very suddenly. It has long been believed that the presence of 1·5 per cent. of manganese made common carbon steel brittle. As early as 1877 a case came to my notice in which, by an error, a lot of rail steel which should have contained about one per cent. of manganese, actually contained about 1·5 per cent., its composition being normal in other respects. It was dangerously brittle.

With further increase of manganese, the metal becomes more and more brittle. Manganese steel with from 4 to 6·5 per cent. of manganese, under certain special conditions, is so brittle that it can be pulverized with a hand hammer. But, as the manganese rises above seven per cent., the ductility of the water-toughened metal increases in a most striking way, till the manganese reaches about thirteen per cent. With further increase of manganese the ductility again diminishes, perhaps as fast as it had risen. This is illustrated graphically in *Fig. 5*, by a curve indicating roughly the elongation to be expected in water-toughened pieces.



INFLUENCE OF THE PROPORTION OF MANGANESE.
ON THE DUCTILITY OF MANGANESE - STEEL.

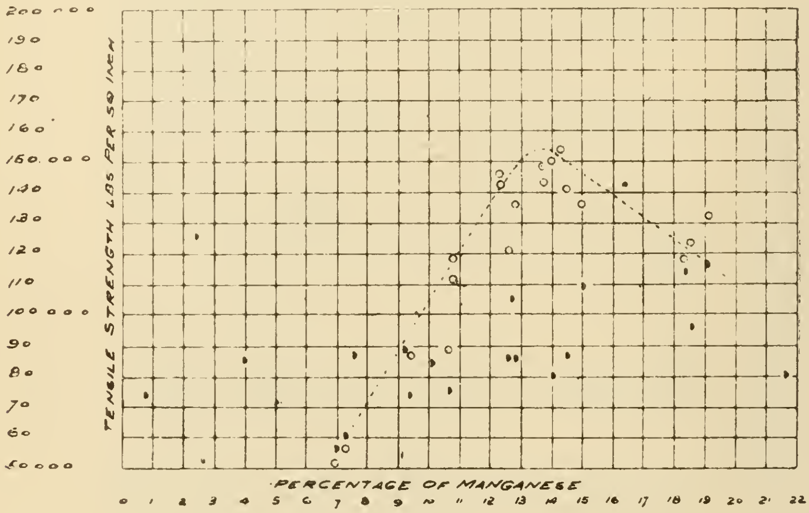
● = Natural state Manganese Steel
○ = Water Toughened

FIG. 5.

Fig. 6 shows in like manner how the tensile strength of water-toughened manganese steel, very low when there is some seven per cent. of manganese present, rises rapidly, reaching a maximum when the manganese reaches somewhere about fourteen per cent., and again diminishing with further increase of manganese.

Returning again to *Fig. 5*, we note that the strength and ductility reach their maxima with about the same percentage of manganese.

But, though striking, the reversal of the effects of increments of manganese on the physical properties of the alloy, as its content of manganese rises above fourteen per cent., is by no means astonishing; for like cases are reported with other alloys. Thus a slight addition of zinc is reported to lessen the malleableness of copper, while a larger addition in turn increases it.



INFLUENCE OF THE PROPORTION OF MANGANESE ON THE TENSILE STRENGTH OF MANGANESE-STEEL.

• = Natural-state Manganese-Steel
o = Water-Toughened

FIG. 6.

Fig. 7 compares the combination of strength and ductility of manganese steel with the same combination for nickel steel. The circles as before represent manganese steel, the triangles nickel steel. The combination as thus measured is seen to be on the whole much greater in manganese steel than in nickel steel. But this does not at all prove that manganese steel is better than nickel steel.

While manganese steel is intensely and astonishingly hard, considering its ductility, it is not as hard as chilled cast iron, nor as the hardest grades of carbon steel when they are dead hardened, that is to say, brought to their very hardest state by quenching in water. Manganese steel containing some seven per cent. of manganese, indeed, is so hard that it can be used for cutting iron; and lathe tools made from it have been used successfully. But the thirteen per cent. manganese steel, with which we concern ourselves this evening, is far from hard enough for this purpose.

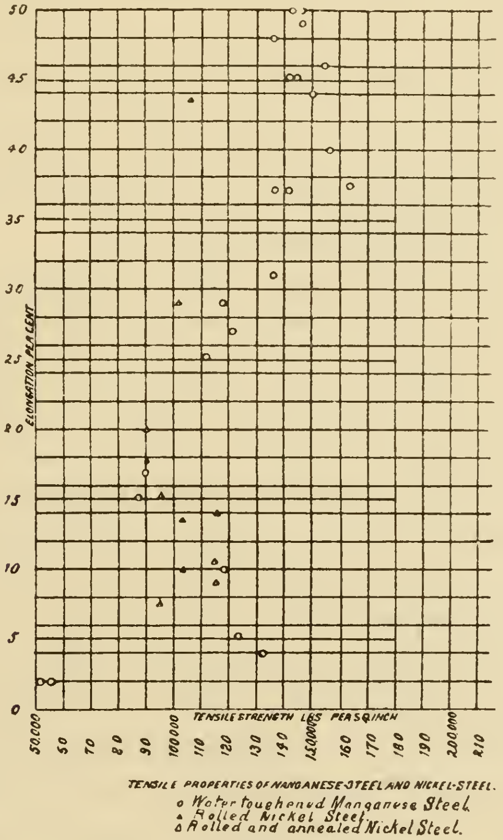


FIG. 7.

Moreover, the very fact that it is accompanied by great ductility, makes its hardness peculiar. We are accustomed to think of very hard bodies as incapable of being indented, as for instance by the blow of a hammer: but manganese steel can be thus indented. This, however, is a necessary consequence of its ductility. Most very hard bodies, such as glass, hardened steel, or chilled cast iron, if they receive a blow which passes their compressive elastic limit, simply break or crack; that is because they are not ductile; they cannot yield. Manganese steel, however, on receiving such a blow simply yields. Within its elastic limit it behaves under blows like other hard substances. Let the blow exceed the elastic limit, and manganese steel yields where the others break.

I am hardly prepared to give a clear account of its rigidity. Under some conditions it has shown itself very rigid; under others it has not. As yet I cannot point out with confidence the conditions which make it rigid in some cases, but not in others.

Manganese steel car axles, struck transversely by a heavy ram, have been found much more rigid than those of carbon steel, with which they were tested competitively. Yet stamp shoes and horseshoes of manganese steel have not thus far shown the endurance expected.

In resistance to abrasion alone, manganese steel excels the hard carbon steels (when unhardened) and, *a fortiori*, the soft steels. Where both abrasion and repeated shocks are to be resisted, manganese steel is certainly far less liable to break than the hard carbon steels; but whether, under new conditions combining shock and abrasion, it will prove as rigid as the carbon steels, with which it will then have to compete, direct experiment alone can tell.

Its magnetic properties, or their absence, are among the most surprising things concerning this surprising substance. While manganese steel of nine per cent. of manganese is attracted by the magnet when finely divided, yet that of thirteen per cent. is for all practical purposes unmagnetizable. With moderate magnetizing force, its susceptibility to magnetic influences is, according to Ewing, only about $\frac{1}{8000}$ that of soft iron. "No magnetizing force to which the metal is likely to be subjected in any of its practical applications will produce more than the most infinitesimal degree of magnetization." Yet with enormous magnetizing force, for instance of 10,000 C. G. S. units, it is possible to magnetize manganese steel very considerably.

If its resistance to magnetization is great, so is its resistance to the passage of heat and of electricity. Of each it is a very poor conductor.

Fig. 8, from determinations kindly made by the Thomson-Houston Electric Company, of Lynn, Mass., comparing the electric resistance of manganese steel with that of copper and of soft iron at different temperatures, shows that the resistance of manganese steel at 0° C. is nearly seven times that of soft iron, and is very much less affected by changes of temperature than the resistance of either soft iron or copper. Its resistance is about double that of platinoid, and thrice that of German silver.

Preparation.—Manganese steel of the class that I am describing to-night is made by stirring together the molten, thoroughly decarburized product of the open-hearth or Bessemer process and molten, highly heated, rich ferro-manganese. Care must be taken to avoid loss of manganese, and to keep the proportion of carbon down. The product should have not less than eleven per cent. of manganese, and not more than 1·25 per cent. of carbon. If we can give it as much as thirteen per cent. of manganese and less than one per cent. of carbon, it will be better for most purposes. So high a ratio of manganese to carbon can be had only through great care.

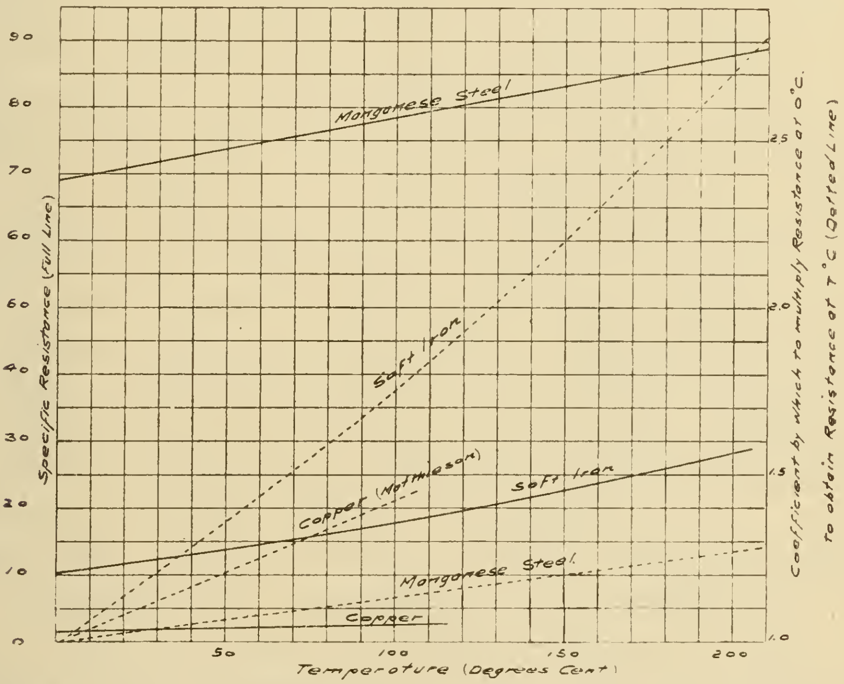


FIG. 8. Electrical resistance of manganese steel, copper and iron.

The high cost of metallic manganese puts it beyond our reach as a material for making manganese steel. The only present available source of manganese for this purpose is the carburetted alloy of iron and manganese called ferro-manganese, made in the iron blast furnace from ores of manganese. It usually contains about eighty per cent. of manganese, six per cent. of carbon and thirteen per cent. of iron, though occasionally the proportion of manganese rises to beyond eighty-seven per cent., with as little as seven per cent. of iron.

These crude products of the blast furnace necessarily contain so much carbon, absorbed directly or indirectly from the fuel, that even those richest in manganese are barely rich enough. The difficulty is to get into the steel as much manganese as it needs, without incidentally introducing an excessive and injurious quantity of carbon. For the requirements just given as to the composition imply that the steel should contain at least nine times, and better thirteen times, as much manganese as carbon. Even if we make no allowance for the fact that the molten decarburized iron usually contains much more carbon than manganese, and that an appreciable quantity of manganese is lost by oxidation in alloying the molten components, this implies that, as the ferro-manganese usually contains at least six per cent. of carbon, it must contain at least $9 \times 6 = 54$ per cent., and better $13 \times 6 = 78$ per cent., of manganese.

In short, to avoid having in our steel more carbon than is desirable, we must use a ferro-manganese as rich as possible in manganese, and alloy it with iron containing as little carbon as possible.

Such iron is that made either in the Bessemer process or in the open-hearth process, by thoroughly decarburizing cast iron. In making merchantable steel (other than manganese steel) by either of these processes, a little carbon or manganese, or both, must actually be added to this thoroughly decarburized iron, in order to make it malleable, for reasons which we need not here consider. But in making manganese steel we deal with simply this thoroughly decarburized iron.

The loss of manganese in preparing manganese steel, according to Hadfield, equals about 0·50 per cent. of the total weight of the decarburized iron plus ferro-manganese used; *e. g.*, if the charge should by calculation, and without allowing for loss of manganese, contain 13·5 per cent. of manganese, it will actually contain about thirteen per cent.

After carefully mixing the molten iron and ferro-manganese, they are poured into suitable moulds of iron or sand, as the case may be. Large ingots are habitually cast in iron moulds; and here an important precaution must be observed.

Thanks to the slowness with which this metal conducts heat, the outside of the ingot, in contact with the cold walls of the iron mould, cools so far as to be rigid and incompressible, while the interior of the ingot is still far above its melting point. In cooling from this exalted temperature the molten, and later the solidified metal of the interior, undergoes great contraction, and no longer suffices to fill completely the outer shell of the ingot. Hence arises a deep vacuous cavity in its centre, known as the "pipe." To meet this, the top of the ingot is covered with charcoal, so as to keep its upper surface molten, and fresh lots of molten manganese steel are from time to time added, in order to fill this cavity or pipe.

Treatment.—We now pass on to consider the treatment of manganese steel. In what may be termed its natural state, *i. e.*, when slowly cooled either from the initial heat of casting or after forging, *manganese steel is brittle.* The ductility which gives it value is obtained only by sudden cooling from a high temperature, *e. g.*, by plunging it while red-hot into cold water.

We are all familiar with the remarkable effect of suddenly cooling common steel, as for instance by plunging it while red-hot into water or oil; we all know how this hardens the metal, makes it relatively brittle, and, if judiciously performed, strengthens it. (In speaking of hardness, I invariably refer to the hardness proper, the resistance to indentation and abrasion.)

But the effects of sudden cooling on manganese steel and on carbon steel are in some respects very unlike. The tensile strength and elastic limit of both may, indeed, be greatly raised by sudden cooling; but even here a difference is noticeable. For while sudden cooling, even if very sudden, indeed violent, increases the strength of manganese steel greatly, the rate and conditions of cooling must, in case of carbon steel, be carefully regulated if great strength be sought; and indeed very sudden cooling may actually greatly weaken carbon steel, and require a subsequent tempering; that is to say, mitigating, or letting down.

When, however, we turn to the effects of sudden cooling on the hardness proper and the ductility of these two substances, carbon steel and manganese steel, we find a most marked difference. Sudden cooling hardens carbon steel greatly, and may make it so hard that it scratches glass readily; if it affects the hardness proper of manganese steel at all, its effect is so slight as to be detected only by delicate tests. Sudden cooling tends to lessen, and if very sudden may quite destroy the ductility of carbon steel, leaving the metal as incapable of receiving permanent set as glass is. Yet the same sudden cooling increases the ductility of manganese steel astonishingly.

Fig. 5 illustrates graphically the influence of sudden cooling on the ductility of manganese steel. Here the properties of manganese steel in its natural state are indicated by black semi-circles, the circles indicating the properties of the metal when suddenly cooled by quenching in water, or, as it is called, "water toughened." We see that, while the elongation of the metal in its natural state is usually below five per cent., that of the water-toughened material rises occasionally to fifty per cent.

Fig. 6 illustrates in like manner the influence of sudden cooling or water toughening on the tensile strength. We note that, while the tensile strength of the metal in its natural state, as indicated by the black semi-circles, rarely rises above 100,000 pounds per square inch, that of the water-toughened metal, indicated by the circles, is usually above 110,000 pounds, and rises to even above 150,000 pounds per square inch.

[*To be continued.*]

MAXIMUM STRESSES FROM MOVING SINGLE LOADS IN THE MEMBERS OF THREE-HINGED ARCHES.

BY EMRICK A. WERNER.

[*Concluded from p. 50.*]

D_{III} *min.:*

$$\text{Maximum line } g_m = 75{\cdot}0$$

$$\text{Minimum span} = \text{space from } (o) \text{ to } (30)$$

$$c \text{ being positive and } \left(\frac{l}{2} - g_m\right) = o$$

$$\frac{d\,D}{d\,g} = 0{\cdot}20\ W_I - w$$

$$W_I = \text{load on left side of arch.}$$

First wheel 112·0 from Abutment B, second tender wheel 1·0 from Abutment A.

$$D_{III}\ min. = \left(\frac{M}{h}\right)_{45} - \left(\frac{M}{h}\right)_{30} = -\ 558 \div 17{\cdot}5 = -\ 31{,}900$$

D_{IV} *min.:*

$$\text{Maximum line} = 93{\cdot}75$$

$$\text{Maximum span} = \text{space from } (o) \text{ to } (45)$$

$$c \text{ being positive and } \left(\frac{l}{2} - g_m\right) = o$$

$$\frac{d\,D}{d\,g} = +\ 0{\cdot}16\ W_I - w$$

$$W_I = \text{loading on left side of arch.}$$

$$D_{IV} = \left(\frac{M}{h}\right)_{6} - \left(\frac{M}{h}\right)_{45} = -\ 907 \div 17{\cdot}5 = -\ 51{,}800$$

$$D_V = -\left(\frac{M}{h}\right)_{60} = +\ 62{,}100$$

Vertical stresses P in the posts.

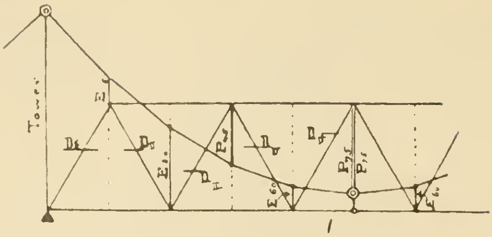


FIG. 33.

P_{75}.—

P_{75} is a maximum and minimum with D_V hence:

$$P_{75}\ max. = \left(\frac{M}{h}\right)_{60} \times tan\ \alpha = 62\text{·}600\ \frac{17\text{·}5}{15} + 73{,}200$$

compression.

$$P_{75}\ min. = \left(\frac{M}{h}\right)_{60} \times tan\ \alpha = 62\text{·}100 \times \frac{17\text{·}5}{15} = 72{,}600$$

tension.

P_{45}.—see *Fig. 33*.

Considering P_{45} as consisting of two coinciding posts, P left and P right, each acted upon by one diagonal, and remembering that in defining P maximum and P minimum that end of the post must be selected, which takes up no moving load, we have:

$$P_{15} = \pm\ (D_{IV} \pm D_{III})\ tan\ \alpha$$

Barring out the cases in which both diagonals are in tension, from which we know the stress will be smaller than that from one diagonal, the above equation becomes:

$$P_{15} = \pm\ (D_{IV} - D_{III})$$

$(D_{IV} - D_{III})$ will be a maximum or minimum, when one of the D's, as the case may be, is equal to zero; — D_{IV} and D_{III} represent the following divisions of W_1 and W_2 (see *Fig. 34*).

Developing we find:

$$h\ D_{IV} = -0\text{·}16\ W_1 g_1 + W_2 (15 - 0\text{·}16\ g_2) + 0\text{·}04\ W_3\ g_3$$

$$h\ D_{III} = -0\text{·}20\ W_1'\ g_1' + W_2' (15 - 0\text{·}20 g_2')$$

$$P_{45} = \pm\ \frac{tan\ \alpha}{h}\ [-\ 0\text{·}16\ \ W_1\ g_1 + W_2\ (15 - 0\text{·}16\ g_2) +$$
$$+ 0\text{·}04\ W_3\ g_3 + 0\text{·}20\ W_1'\ g_1 - W_2'\ (15 - 0\text{·}20\ g_2')\ ]$$

and

$$\frac{dP}{dg} = \pm [0.16 (W_1 + w) + 0{\cdot}16\ W_2 + 0{\cdot}04\ W_3 - w -$$

$$- 0{\cdot}20 (W_1' + w') - 0{\cdot}20\ W_2' + w']$$

$$W_1 + w + W_2 = W_1' + w' + W_2' = W_1$$

$$\frac{dP}{dg} = \pm [0.04 (W_3 - W_\mathrm{I}) - (w - w')]$$

Making $b = o$ in the above general equation of P_{45}, we find:

$$g_\mathrm{m} = 93{\cdot}75\ P \text{ left} = \frac{15}{0{\cdot}16}$$

$$g_\mathrm{m}' = 75{\cdot}0\ \ P \text{ right} = \frac{15}{0{\cdot}20}$$

both maximum lines run to the top hinge, and $(g_\mathrm{m} - a)$ reaches from (45) to (75) and from (60) to (75). Hence the signs of b and b' be positive, and the signs of the coëfficients, as shown in *Fig. 34*.

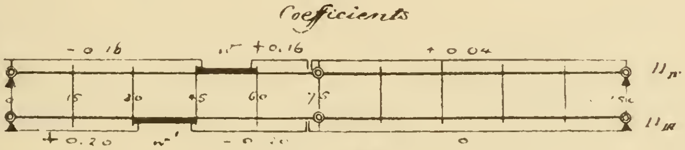


FIG. 34.

Maximum P_{45}.—

With these signs we find the maximum span of P_{45} in taking those parts of the truss corresponding to positive values of the *combined* coëfficients of P right (D_IV) and P left (D_III).

In our case the combined action of a and $a' = 0{\cdot}20 - 0{\cdot}16 = 0{\cdot}04$ will be positive from (o) to (30). From point (30) to point (60) the coëfficients are negative, from (60) to (75) the combined action of c and c' is $(15 - 0{\cdot}16\ g_2) - (15 - 0{\cdot}20\ g_2)$. This difference gives for $g_2 = 60$ the value + 2·4, for $g_2 = 75$ the value + 3. The combined action of c and c' is thus positive. From (75) to (150) c is positive.

We have thus for the maximum span the following diagram:

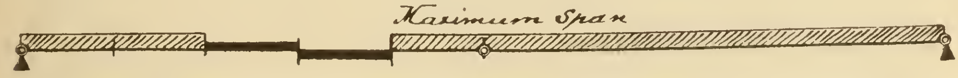


FIG. 35.

and the condition of P_{45} max. will be $(w - w')$ being equal to zero.

$$\frac{d\,P}{d\,g} = W_3 - W_1$$

$$D_{IV} = o$$

W_1 = load on left side of arch.

We find the corresponding position

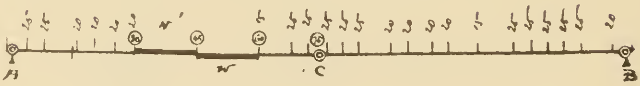


FIG. 36.

in shifting the position answering $W_3 - W_1$ until D_{IV} becomes zero.

From this position follows:

P_{45} *max.* = 50,100 compression.

Minimum P_{45}.—

The minimum span of P_{45} embraces those parts of the truss corresponding to negative values of the combined coëfficients $a\ b\ c\ \beta$, as shown in *Fig. 37*,

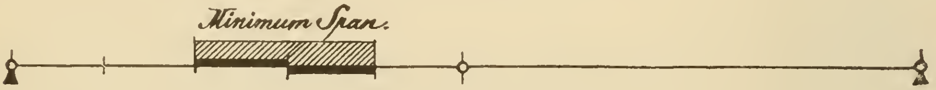


FIG. 37.

and the conditions of P_{45} min. are:

$$\left[\begin{array}{l} \frac{d\,P}{d\,g} = w - w' \\ D_{III} = o \end{array}\right.$$

We find accordingly

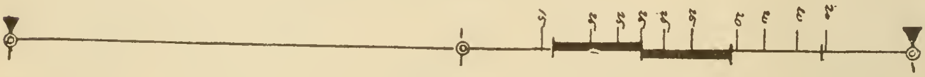


FIG. 38.

giving P_{45} minimum = 60,500 pounds tension.

Stresses in the hangers.—

The maximum and minimum corresponds to the maximum and minimum loading of the floor beam. The minimum is equal to zero. The condition of maximum is:

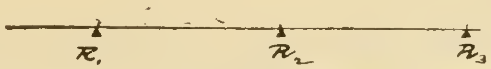


FIG. 39.

$$\frac{d\,p}{d\,g} = 2\,W_1 - W$$

whence

$$p = \frac{(R_2 - R_1) - (R_3 - R_2)}{\Delta_x} = 82{,}500 \text{ pounds.}$$

With these values we find now the stresses in the members themselves.

Stresses in the cable.—

$$H \div \cos \mu$$

Maximum:

First panel	467,000 pounds.
Second panel	434,000
Third panel	408,000
Fourth panel	390,000
Fifth panel	380,000

Minimum = *o*

Vertical stresses in suspension rods.—

$$E_x = H\,(tan\ \mu_{x + \Delta x} - tan\ \mu_x)$$

Maximum = 60,000

Minimum = *o*

Stresses in the chords.—

$$C_x = \left(\frac{M}{h}\right)_x$$

From the sign of *D* must be found the direction of the chord stresses.

This is done with triangular trusses in the easiest way, in introducing the diagonals as diagonals in tension in a truss with similar rectangular panel division, and in transferring the chord pieces of those panels, in which the diagonals have the same position in both trusses, into the triangular truss.

We find in this way

Maxima (positive moments):

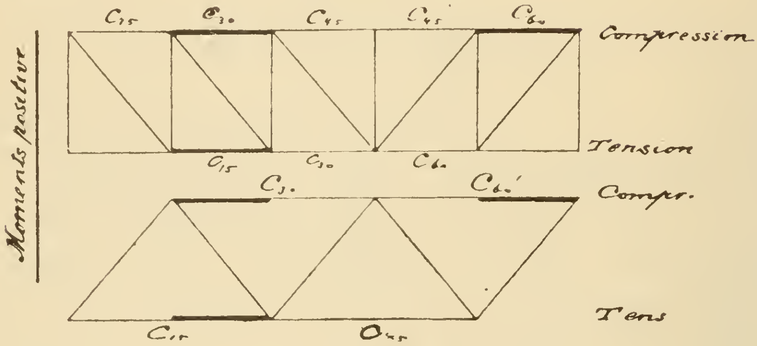


FIG. 40.

Top Chord:

Second and third panel 108,200

Fourth and fifth panel 62,600

Bottom Chord:

First and second panel 79,300

Third and fourth panel 103,900 (tension)

Minima (negative moments):

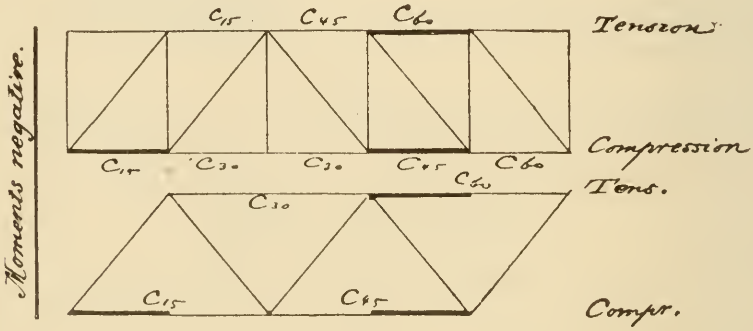


FIG. 41.

Top Chord:

Second and third panel 104,000 tension.

Fourth and fifth panel 62,100 tension.

Bottom Chord:

First and second panel 71,500 compression.

Third and fourth panel 99,700 compression.

Stresses in the diagonals.—

$$D \div \cos \alpha = D \div 0{\cdot}651$$

Calculate as for truss with square panels and reverse the stress in the reversed diagonals.

Maxima:

First panel	— 122,000
Second panel	+ 71,600
Third panel	— 48,900
Fourth panel	+ 75,300
Fifth panel	+ 96,200

Minima:

First panel	+ 109,700
Second panel	— 55,500
Third panel	+ 49,000
Fourth panel	— 79,600
Fifth panel	— 95,400

Vertical stress in the posts.—

P_{45} = 50,100 compression.
60,500 tension.

P_{75} = 73,200 compression.
72,600 tension.

Hangers:

82,500 pounds.

DEAD LOAD.

As in the first example (upright arch) the dead load is assumed at 26,000 pounds per panel point. As H, R and M have the same value in both examples, we have,

Stress in the cable = stress in the lower chord of example *I*.

Stress in the suspension rods.—

$$E = H\,(\tan \mu_{x+\Delta x} - \tan \mu_x) - p' = 0{\cdot}16\,H - p' =$$

$$= 26{,}000 - 8{,}000 = 18{,}000 \text{ pounds.}$$

Stress in the chords = 0

Stress in the diagonals = 0

Stress in the posts:

$$P_{75} = -\ 2{,}000 \text{ pounds.}$$

$$P_{45} = -\ 4{,}000 \text{ pounds.}$$

Stress in the hangers = 14,000 pounds.

With these figures the following strain sheet is computed:

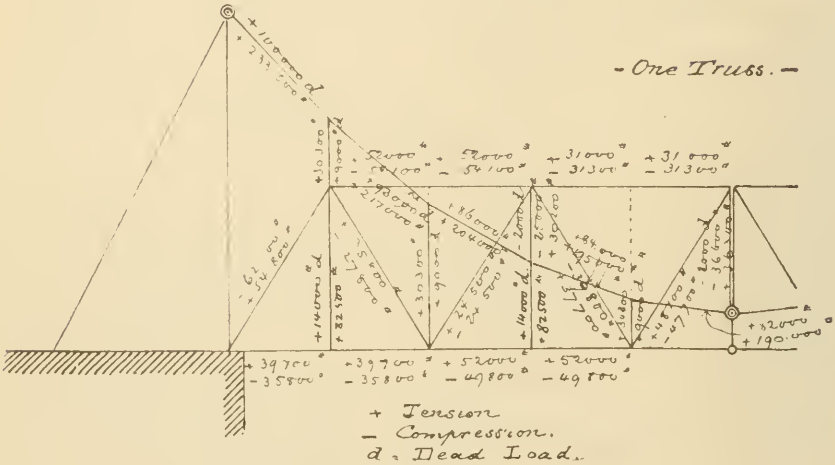


FIG. 42.

The examples are selected merely with the intention of showing in the smallest space all the casualties of actual figuring. They give in no way data for comparing arched trusses and trusses with vertical reactions only.

The calculations are given in full length with the possible checks. In actual figuring much of this work can be avoided.

PROCEEDINGS

OF THE

CHEMICAL SECTION

OF THE

FRANKLIN INSTITUTE.

[*Stated meeting held Tuesday, January 17, 1893.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, January 17, 1893.

Dr. Wm. H. Greene, President, in the chair.

Dr. Wahl nominated Mr. Joseph Richards, 1802 Catharine Street, Philadelphia, and Mr. Jesse Jones, care of Messrs. Wm. Cramp & Sons, corner York and Thompson Streets, Philadelphia, for full membership in the Section. After action by the Committee on Admissions these gentlemen were declared elected.

Dr. Greene, as chairman of the committee appointed to consider the subject of securing additional papers for the meetings of the Section, made the following report:

"The committee to which was referred the suggestions of Dr. Day that, at stated intervals, reports should be prepared for the Chemical Section on the progress in certain lines of Chemical investigation, respectfully recommends:

"That at every alternate meeting of the Section a conference be given by one of the members, covering the development of some point that may be of general interest to the Section;

"That a committee of three be appointed to serve during the ensuing year for the purpose of securing members or others to give at least five such conferences.

"On inquiry, the committee has found that a number of members are willing to undertake the preparation and presentation to the Section of informal lectures on new developments of the science, and believe that such conferences and general discussion of the subjects considered cannot fail to be of interest to the members, and to increase the attendance at the meetings."

In accordance with this report the President named as members of the committee for 1893, Dr. Wahl, Chairman, Dr. Keller and the Secretary.

The same members as for last year were continued on the Committee on Admissions.

The President appointed Mr. Haines and Dr. Keller members of the Finance Committee.

Dr. Wahl suggested that the Chemical Section might, with advantage to the Institute, exercise the function of securing the lectures on chemical subjects in the general course of lectures annually given by the Institute. He further recommended that the suggestion be left for the present, in order to give time for due consideration by the members with a view of taking official action upon it later in the year.

Dr. Greene then read a highly interesting paper, for himself and Dr. Wahl, on "A New Process for the Production of Manganese on the Commercial Scale."

The paper was referred for publication.

After an animated discussion, partaken in by many of the members present, the Section adjourned. WM. C. DAY, *Secretary.*

PROCEEDINGS
OF THE
ELECTRICAL SECTION
OF THE
FRANKLIN INSTITUTE.

[*Stated meeting, held Tuesday, December 27, 1892.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, December 27, 1892.

Mr. Elmer G. Willyoung, President, in the chair.

Present, sixteen members and visitors.

The minutes of the previous meeting were read and approved.

Two nominations to membership were referred to the Committee on Admissions. The committee reported two elections since last meeting.

The following were elected officers for 1893:

President—Mr. Elmer G. Willyoung.
Vice-Presidents—Prof. Edwin J. Houston and Mr. C. W. Pike.
Secretary and Treasurer—Prof. L. F. Rondinella.
Conservator—Dr. Wm. H. Wahl.

Mr. Edwin F. Northrup read a paper on "Some Principles that must be Observed in the Construction of a good Closed-circuit Battery and some new Portable Dry Cells in which they are Applied." (First paper.) Referred for publication.

The chair called attention to the desirability of full discussion upon papers, and the importance of members hearing papers when read or receiving an abstract beforehand, if possible.

It was moved and carried that the Committee on Papers be authorized to send out abstracts of forthcoming communications with the meeting notices, whenever possible.

Adjourned. L. F. RONDINELA, *Secretary.*

PROCEEDINGS.

[*Stated meeting, held Tuesday, January 24, 1893.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, January 24, 1893.

Mr. E. G. Willyoung, President, in the chair.

Present, thirteen members and visitors.

The minutes of the previous meeting were read and approved.

The Secretary and Treasurer presented his annual report for 1892, which showed the Section to be in an active and prosperous condition. It was accepted and referred for publication.

The Treasurer reported the cash balance in the treasury, and presented bills for printing and clerical work, which were approved and ordered paid.

The Committee on Admissions reported two elections to membership since last meeting.

Mr. R. C. Hindley's resignation of active membership was presented and accepted.

A communication was read from the Secretary of the Institute, desiring information as to whether the Section would wish to publish an annual volume of its proceedings for this and future years, as the matter would all be printed in the monthly *Journal of the Institute*, and sent gratuitously to each member. Upon motion, the President and Secretary were appointed a committee to confer with the Publication Committee upon this subject.

On account of ill health from over-work, Prof. Rondinella regretfully offered his resignation as Secretary and Treasurer of the Section, to take effect upon the election of his successor at the February meeting. It was accepted with regret.

Mr. Edwin F. Northrup read the second part of his paper on "Some Principles that must be Applied in the Construction of a good Closed-circuit Battery, and some new Portable Dry Cells in which these Principles are Applied." Referred for publication. The paper gave the results of a most complete series of experiments, and was discussed by Messrs. Stradling, Willyoung, Billberg and Winand.

Prof. Geo. F. Stradling's paper, on "The Migration of the Ions," was deferred until next meeting.

Upon motion a committee of three was appointed to prepare and present a review of each month's electrical progress at the regular meetings of the Section.

The meeting then adjourned. L. F. RONDINELLA, *Secretary.*

SOME NEW APPARATUS FOR THE MOST EXACT COMPARISON AND ADJUSTMENT OF RESISTANCE STANDARDS AND THE DETERMINATION OF TEMPERATURE COËFFICIENTS.

BY ELMER G. WILLYOUNG.

[*Read at the stated meeting, held November 22, 1892.*]

A little over a year ago I had the honor to present to the notice of the Section some general considerations with reference to the manufacture and adjustment of standard resistances.* During the course of the paper which I then read I exhibited and explained the operation of, to the Section, a piece of apparatus originally suggested to me by Prof. H. S. Carhart, of Michigan University,† and later modified by myself and intended for the very exact comparison and adjustment of standards and the determination of their temperature coëfficients. This apparatus was then and still is being used by Messrs. Queen & Co. as part of their equipment for the commercial doing of this work. This piece of apparatus I have not here to-night, but will sketch it upon the board later in order to bring its details clearly before us. I expressed myself, at that time, as believing it to be perfectly simple and easy to quickly adjust any single standard of resistance by the aid of this apparatus with a certain accuracy of $\frac{1}{100}$ per cent. Since the reading of that paper this method and apparatus have been in constant daily use in our laboratory, and my belief is its convenience and accuracy has been confirmed and strengthened. In the use of the apparatus we have, I think, at one time or another, been obliged to note every weak point in its theory or construction, and to provide such temporary means as might be obtainable for getting around difficulties as they arose. On a basis of an experience thus obtained I have recently designed and built an improved form of this apparatus, which is in every way greatly superior to the apparatus I then showed, and which I believe, from reports which I have received of the apparatus used at the leading laboratories of the world for this same purpose, is capable of giving closer comparisons, and of being used to obtain the value of a single standard to a higher degree of accuracy than any other arrangement of apparatus in the world; with this improved apparatus in the hands of a skilful observer, I consider it entirely possible to determine the value of one coil in terms of another to an accuracy of $\frac{1}{400}$ per cent. and even greater.

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* "Resistance Standards: their Manufacture and Adjustment," *Journal of the Franklin Institute*, April, 1892.

† The first apparatus, made according to Prof. Carhart's design, was made by me either in 1887 or 1888, while I was still a student at the University. It is still in the laboratory there, and in constant use, and is, I am told, as good as ever.

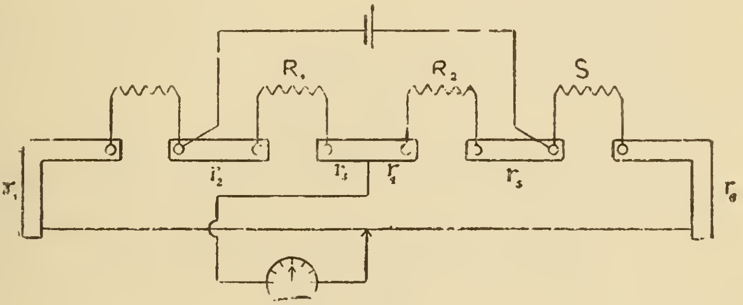

FIG. 1.

As the details of the arrangement and method are not fresh in the memories of most of you, I will hastily run over the general theory of the method, and of its application by means of the early apparatus, and then set forth the improvements which have been made and embodied in this newest form. Let *Fig. 1* represent, diagrammatically, the orthodox slide wire bridge in which X is the unknown resistance (nearly equal to the coil S), to be accurately measured in terms of S, and R_1 and R_2 are resistances roughly equal to one another and to S. The balance reading will then fall near the centre of the bridge. The heavy copper end straps are of resistances which may be designated by r_1 and r_6, the resistance of the other connectors by

r_2, r_3, r_4 and r_5, as shown. When a balance is obtained, we have

$$\frac{R_1 + r_2 + r_3}{R_2 + r_4 + r_5} = \frac{X + r_1 + x_1 \rho}{S + r_6 + (L - x_1) \rho} \qquad (1)$$

x_1 being the reading;

L being the whole length of the bridge wire;

ρ being the resistance of a single division of the bridge wire.

Reversing the position of X and S, and balancing again, we have

$$\frac{R_1 + r_2 + r_3}{R_2 + r_4 + r_5} = \frac{S + r_1 + x_2 \rho}{X + r_6 + (L - x_2) \rho} \qquad (2)$$

From (1) we have

$$\frac{R_1 + r_2 + r_3}{R_1 + R_2 + r_2 + r_3 + r_4 + r_5} = \frac{X + r_1 + x_1 \rho}{X + S + r_1 + r_2 + L \rho} \qquad (3)$$

and from (2)

$$\frac{R_1 + r_2 + r_3}{R_1 + R_2 + r_2 + r_3 + r_4 + r_5} = \frac{S + r_1 + x_2 \rho}{X + S + r_1 + r_2 + L\rho} \qquad (4)$$

$$\therefore \quad X + r_1 + x_1 \rho = S + r_1 + x_2 \rho \qquad (5)$$

and

$$S - X = \rho (x_1 - x_2)$$

or

$$X = S - \rho (x_1 - x_2) \qquad (6)$$

so that the unknown X differs from the standard S by exactly the resistance of the bridge wire over which the slider moves in changing from one position of balance to the other when the coils X and S are interchanged; we also see that the expression is entirely independent of the *length* of the bridge wire, and also of the resistance of the connecting coppers. We may, therefore, measure as small differences as we please by merely making the resistance of our bridge wire small enough.

I will now sketch the earlier apparatus, *Fig. 2*. This was a device for quickly and easily interchanging the two coils, X and S, of *Fig. 1*. Upon a suitable insulating base are mounted a number of copper straps and plates as shown; these are so arranged as to place four coils in exactly the same relation to one another as in *Fig. 1*. The lettering upon the two figures is the same. The coils X and S have their terminals resting in mercury cups; the coils R_1 and R_2, being eliminated in the measurement, are simply fastened firmly into the binding posts. The galvanometer and battery circuits are as shown. In the centre of the apparatus are seen two groups of mercury cups, each group forming a square; these groups are connected together, as shown, by the heavy copper rods C. By now running around the circuit from the left, clockwise, it will be seen that the order of the four coils is exactly the same as in *Fig. 1*. If, now, we alter the position of the heavy connecting rods C, to the position indicated by the dotted lines, the coils X and S will be interchanged as will be readily obvious by again following around the circuit. In

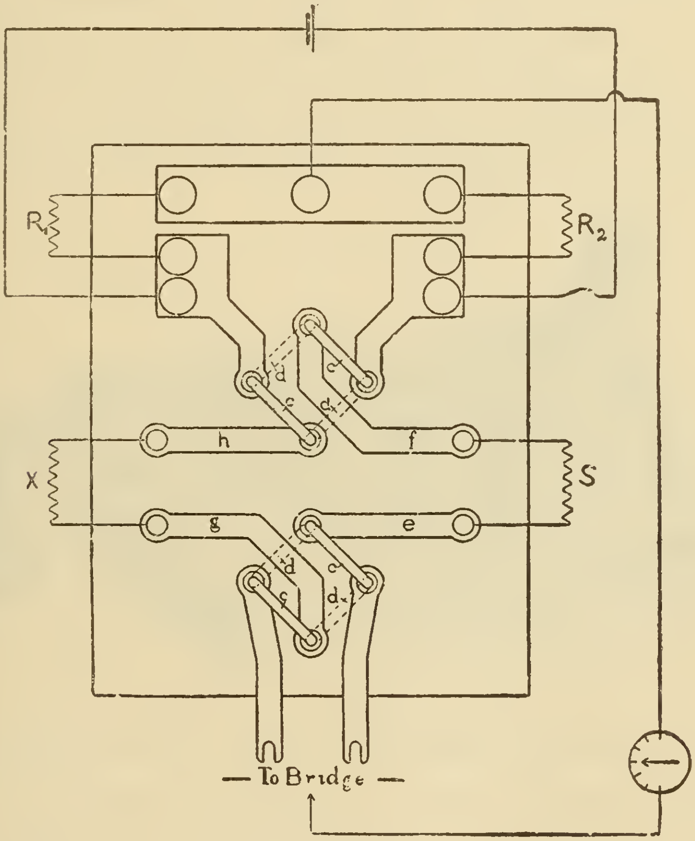

FIG. 2.

practice each *pair* of connectors is held in a little hard rubber platform, *C*, *Fig. 3*, so that but two movements are required to effect the change; being held loosely in the platform they will adjust themselves to the surface of the bottom of the cup, and thus make thoroughly good contacts. Inspection will show that this apparatus is a perfectly symmetrical arrangement, and that, consequently, the connector resistances need not be considered: thus, with the commutator rods as shown by the heavy lines, and passing around the circuit from the bridge, clockwise, we have in circuit on the left, g, X and h, the other pieces being very obviously *pairs*, and on the right f, S and e. Turning the commutator through 90° to the positions indicated by the dotted lines, starting from the left again we have c, S and f, and from the *right* g, X and h; since $e = h$ and $f = g$, it is the same whether they are on one side or the other, and therefore only the resistances X and S have really been interchanged. To *use* this apparatus it is only necessary to insert the two slotted terminal straps into one of the gaps of an ordinary slide wire bridge. In the work which we have been doing we have been using a special form of slide bridge designed by myself, and having three wires, each a metre long, which can be thrown into multiple with one another if desired.

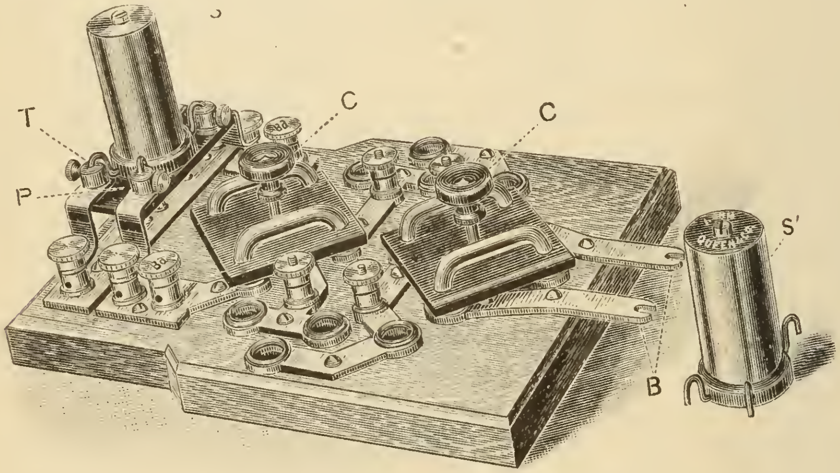

Fig. 3.

Having thus described the earlier form and arrangement of the apparatus I will now speak of its inconveniences and defects. The first one arises when we attempt to obtain the value of the resistances of the bridge wire per unit division. This, of course, might be obtained by connecting the ends of the wire directly to a Wheatstone's bridge arrangement and obtaining its resistance by ordinary methods. The resistance, however, is necessarily very low, as we shall see from the following considerations: Suppose we have a standard ohm and a resistance of platinoid nearly equal to the ohm, whose temperature coëfficient we wish to exactly determine. We place our two coils in oil baths with both at (say) 15° C. and obtain a balance; we then carefully raise the temperature of the platinoid to (say) 30° C., and balance again. The difference, in terms of resistance of the bridge wire, will be the actual increase in resistance of the platinoid. The rise of resistance of platinoid per degree C. is about 0·00023; multiplying this by 15 and we have 0·00345 ohm as about the actual increase of resistance due to the raising of the temperature from 15° C. to 30° C. Let us suppose also that the value of the coëfficient must be obtained to the fifth decimal place, or in other words that the resistance 0·00345 must be measured with a maximum error a trifle less than 0·00008 of an ohm. With the average slide wire bridge a skilled observer is able to set the slider, it may be assumed, successively, with an error of setting not less than about $\frac{1}{10}$ mm. Consequently $\frac{1}{10}$ mm. of the wire must measure at least as low as 0·00008 ohm, and hence the whole wire 1,000 mm. long will measure 10,000 times this or $\frac{8}{10}$ ohm. To measure even as low a resistance as this even to $\frac{1}{25}$ per cent. is not at all an easy matter by ordinary methods. In practice the resistance of a metre wire should be as much less than the value given above as possible as a greater *length* of wire would then be used when X or S were changed; its non-uniformity would, consequently, become relatively less important, and errors of setting would bear a smaller ratio to the whole length used. It would also be much better, if possible, to measure the resistance of the bridge wire in terms of the resistance of the standard itself, as we would thus eliminate any difference of adjustment between the single standard and any box which we might use for the purpose of measuring the resistance of the bridge wire by ordinary methods. We are, indeed, able to very accurately use this method and apparatus in measuring its own bridge wire. To do this we merely place a heavy short copper strap of negligable resistance in place of X and a resistance Q, somewhat less than the resistance of the single wire, at the right (diagram of *Fig. 1*). Taking our two balances as before, we have from (6)

$$Q - o = \rho\,(x_1 - x_2) \therefore \rho = \frac{Q}{x_1 - x_2} = \frac{Q}{\delta_1} \qquad (8)$$

To find now, the resistance of Q place it in multiple with the standard S, at the right, and again determine the difference, in this case S_2, we shall have

$$\frac{Q\,S}{Q + S} = \rho\,\delta_2 \qquad (9)$$

and eliminating Q between (8) and (9) we have

$$\rho = S \cdot \frac{\delta_1 - \delta_2}{\delta_1\,\delta_2}$$

A third way, which I have used a great deal, is to place a standard one and ten-ohm coil in multiple upon one side against a standard one-ohm coil upon the other. In the early form which I have described it was very difficult to accomplish any of this placing in multiple as there was but one pair of mercury cups upon a side; consequently, we were obliged to make an accessory double pair of cups with connectors to hook into the regular standard cups; this introduced another mercury contact, in itself a bad thing, and also an additional copper resistance which disturbed the symmetry of the apparatus, and hence, the rigid accuracy of the equations preceding. In the improved design of apparatus which I have here, *Fig. 3*, provision has been made for the placing, if desired, of two coils upon each side, and this in a way which does not in the least disturb the original symmetry of the apparatus. In the diagrammatic sketch of this, *Fig. 4*, there is shown a ten- and one-ohm coil in multiple on one side against a one-ohm on the other side; observe, also, that the cups are so placed that the coils clear one another perfectly, and have ample room about them for the necessary oil or water-bath. The distance between these cups is one and five-sixteenths inches, the usual distance between terminal coppers of the B. A. form of standard, which distance will, for the sake of uniformity, probably be retained by all instrument makers for a long time to come.

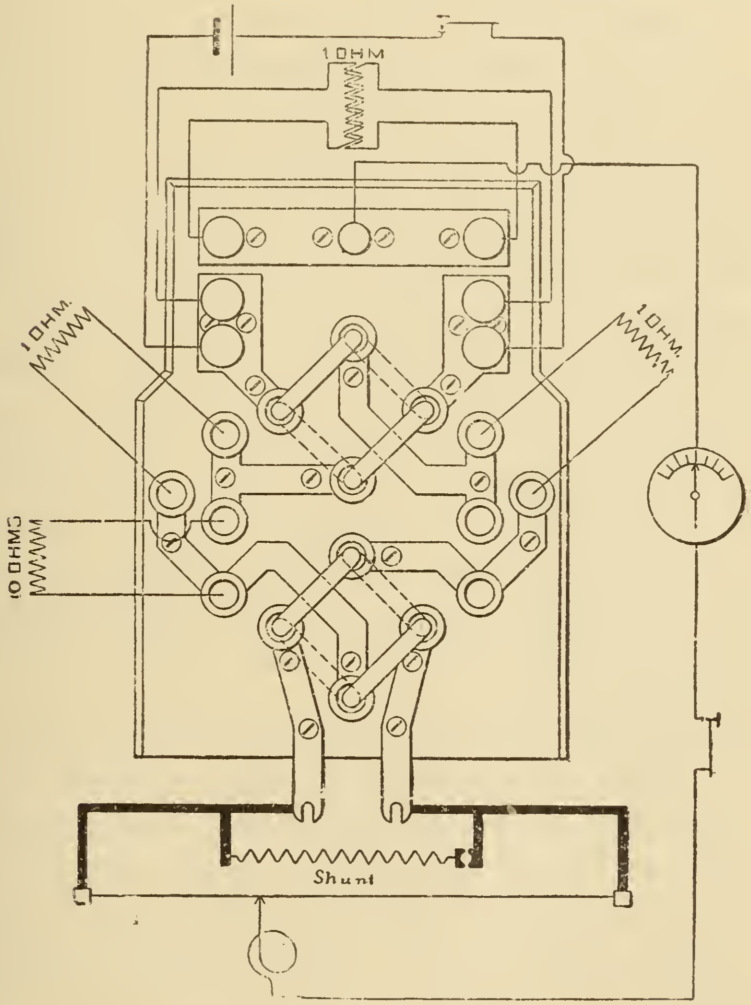

FIG. 4.

The resistance of the coils R_1 and R_2 disappears in the course of the measurement, as is seen from inspection of equations (5) and (6). It is hence not necessary that the *value* of these resistances be known; all that is desired is that they should be *approximately* of the resistance of the coils under comparison in order that the balance may fall near the centre of the wire, and that their resistance should not change during the progress of the measurement. To insure this latter it is sufficient to wind the two coils upon the same spool, and in the first apparatus I ever made of this kind, while I was in the laboratory at Ann Arbor, these two coils were simply enclosed in a plain round wooden box. Later on it occurred to me, however, to place them upon a spool mounted upon a little stand having a pair of terminals upon each side fitting into the binding posts at *T*; the apparatus was thus compacted and made better appearing, and the coils could be more readily removed and others substituted in case standards of a greater or less value were to be compared. In this last design the spool itself is so made as to be removable from the *platform* instead of the whole platform having to be taken off. The terminals of the platform end in little copper binding posts *T*, which receive terminal rods coming from the coils themselves; these coils are wound upon a spool enclosed in a small cylindrical brass case *S*, mounted upon a rubber sub-base *P*. Each case has engraved upon its top the values of the enclosed resistances, as “ $\overset{2}{\text{one-ohms,}}$ ” “ $\overset{2}{\text{ten-ohms,}}$ ” etc. If we desire to adjust ten-ohm standards instead of one-ohm standards, we merely unscrew the little milled head screws, at the side of *T*, lift off the spool and replace it by another one of suitable value.

I stated above that, in our laboratory, we are using a three-wire slide metre bridge of special design. At one time we thought this a very fine thing, but have modified our opinion and now consider it a very ordinary piece of apparatus. It is, to be sure, much better than the average bridge to be met with; what I mean is that compared with what we have learned how to make, this bridge is quite a poor affair. In the first place, I believe any design of a Wheatstone's bridge which is intended for exact work is fundamentally bad if it makes use of a straight wire of any length stretched between two points. I have several reasons for this belief. A bridge used in the average laboratory cannot but be subjected to considerable variations of temperature from one time to another; sometimes this will not be over 5° or 10° for an entire month at a time;

again it may be 20° in about as many hours. As the bases of most slide-wire bridges have been of wood having a coëfficient of expansion considerably different from those of the German silver or platinum iridium wires mounted upon them, it is evident that their temperature variations must produce, at times, considerable strain upon the soldered junctions of wire and end pieces when the wire has been tightly stretched, and it *must* be tightly stretched if good work is done. Probably the greatest strain, however, does not arise so much from the difference of expansion coëfficients as from the change produced in the dimensions of the wooden support by reason of its absorbing or giving out moisture; for purposes of instrument construction it is practically impossible to find wood so well seasoned as not to deform in a very short time. It is, consequently, not surprising that very few straight slide wires ever remain in position very long. In fact, I have never yet seen a straight wire bridge upon a wooden base, with wire stretched tightly enough to make an accurate measurement, whose wire would hold fast without pulling out for a week. The only remedy is to either place the wire upon a compensating base or else to arrange the wire so that it may be slackened when not in use. In the "three-wire" bridge previously spoken of, the wires were fastened to sliding copper end plates which could be tightened and fastened to the end pieces proper by having copper connecting straps. But this having to tighten the wires is a nuisance, requires some strength, and is apt to mean slightly different settings and consequent lengths of wire at different times. I have here a design of a three-wire straight bridge which we have just completed and from which the first instrument is now being made in our shop. Instead of a solid base the support for the wires will be a skeleton frame work of brass rod, the coëfficient of expansion of which is not very far distant from that of the alloys which are usually used for bridge wires. A straight wire bridge has, however, still another defect, to my mind, fully as serious as the one mentioned. This is the tendency to the development of thermal currents, particularly where the wire is joined to the end coppers;

the ends of the wire being a metre apart it is entirely possible and indeed probable that differences of temperature will exist in the air at the two ends of the wire of sufficient amount to develop thermal electro-motive forces of very appreciable values. To make perfectly clear how important a consideration this is I must again refer to the theory of this "Carey-Foster" method. Let us assume that we are comparing two standard ohm coils together and that we wish to know one in terms of the other to an accuracy of $\frac{1}{200}$ per cent., *i. e.*, that we must have a deflection of the galvanometer needle when the slider is but $\frac{1}{20000}$ ohm from perfect balance. We will assume that we are using one cell of battery giving about one volt effective E. M. F. at the junction with the bridge arms. Since there are two ohms on each side the fall through $\frac{1}{20000}$ ohm is $\frac{1}{40000}$ volt. Let us also assume the bridge wire to be German silver, and the terminal ends to which the wire is fastened copper. The thermal E. M. F. of this couple assuming that the one end is at a temperature of 19° C. and the other at 21° C., a difference of but 2° C. is, according to Professor Tait's table of thermo-electric heights,*

$$\begin{array}{rrr} \text{German silver} & -\ 1{,}207 & -\ 5{\cdot}12\ t \\ \text{Copper} & +\quad 136 & +\ {\cdot}95\ t \\ \hline & -\ 1{,}343 & -\ 6{\cdot}07\ t \end{array}$$

$$\text{E. M. F. per degree} - 1{,}343 - 6{\cdot}07 \times 20 = 1{,}464 \text{ C. G. S.}$$

$$\text{E. M. F. of couple } 1{,}464 \times 2 = 2{,}928 \text{ C. G. S.} = \frac{3}{100{,}000} \text{ volt.}$$

This value just obtained is a trifle greater than the E. M. F. which must be detected by the galvanometer and will, of course, throw our observations out by exactly the same amount and prevent our obtaining the required accuracy. If this happens when there is only 2° difference between the ends and when but $\frac{1}{200}$ per cent. is aimed at, how will it be when there is 4° or 5° difference, as there often is, and an accuracy of $\frac{1}{300}$ or $\frac{1}{400}$ per cent. to be attained, and in addition innumerable other thermal E. M. F.'s due to other portions of the apparatus?

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* Everett's *Units and Physical Constants*, 2d ed., pp. 174.

Of course, there are other ways of eliminating the influence of thermal currents. The simplest is to use the galvanometer in place of the battery and to close the battery circuit upon the bridge wire. This plan is, however, not to be recommended. Another good way is to reverse the battery current, the thermal E. M. F., thus acting at one time *with* and at another *against* the battery E. M. F.; the mean of the two is then the balance reading. This is easily accomplished in the apparatus which has been diminished by first taking readings with commutators turned parallel and then with commutators at right angles; *e. g.*, (*Fig. 5*), there would be four commutator positions necessary, as below:

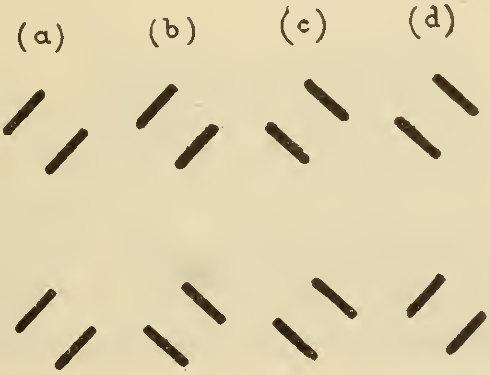


FIG. 5.

The difference of the mean of (*a*) and (*b*) and the mean of (*c*) and (*d*) would represent the desired difference between *X* and *S*, which we desire.

The orthodox straight-wire bridge also occupies considerable space and spreads the apparatus necessary for many of the more common measurements out in an undesirable manner, besides in the case of regular Wheatstone bridge work requiring one to get himself into all sorts of impossible positions in order to obtain and read his balance. On account of all these reasons, I personally favor a wire bridge, having the wire bent one or more times about a circle or cylinder rather than the straight-wire pattern. A circular-wire bridge, if well made, does all that the straight pattern will do and does it much more conveniently; it occupies but little space and brings the readings where they can easily be read; the ends of the wire are close together, so that there is practically no difference in temperature between them and the form is necessarily such that the wire cannot pull out of the end junctions. The contact also is usually a rolling wheel contact giving a tangent point of contact, and hence is not liable to injure the wire, as are most of the cutting "knife edge" contacts on the usual forms of straight bridge. These conclusions as to the relative efficiency of straight and circularly laid wires in slide-wire apparatus are not merely theoretical; they are practical, having been founded upon my own personal experience with both types in the making of very accurate measurements, and upon the experience of those associated with me, who are using the method every day in commercial work.

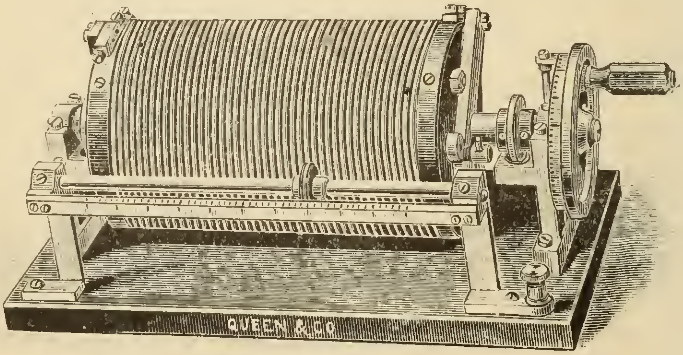


FIG. 6.

I have, therefore, designed and constructed a cylindrical arrangement of bridge wire to go with this latest form of commutating device just described. This is shown in *Fig. 6*, and in diagram in *Fig. 7*. The wire is here coiled upon a polished hard rubber cylinder 4 inches in diameter and 7 inches long; this cylinder is highly polished and the wire stretched in a screw thread cut in its surface. There are fifty turns of wire upon the cylinder. In front of the cylinder is a scale running the entire length of the cylinder, and between the cylinder and scale a small wheel sliding upon a bar carried by the same supports as the scale. This wheel bears snugly against the wire, the end supports being strips of spring brass. Its circumference is platinized and turned to as true a circle as possible, so that the tangent contact is very sharp and definite. As the cylinder is caused to revolve upon its axis, by turning the handle at the end, the little contact wheel travels along the scale always in contact with the wire. The long scale indicates how many complete turns have been made. In order to obtain the fraction of a turn the wheel at the end is divided into 100 parts and each of these parts is easily divided, by the eye, to tenths. This graduation is read by reference to a zero mark at its side, visible in the cut. The bridge wire is thus divisible into 50 × 100 × 10 = 50,000 parts. In order, however, to measure accurately the extremely small resistances represented by the increase of resistance of (say) a platinum silver one-ohm standard for 10° C. increase of temperature, we must have a lower resistance bridge wire than could be obtained by bending any *flexible* wire upon a cylinder but four inches in diameter. The wire has, consequently, been shunted by two shunts placed inside the cylinder itself; these shunts are such that the total resistance of the bridge wire may be either one-ohm or $\frac{1}{10}$ ohm, as desired, and are arranged so that either may be used by simply plugging in a small plug at the end of the cylinder. If we use the $\frac{1}{10}$ ohm shunt the smallest difference measurable with the combined apparatus is $\frac{1}{50000} \times \frac{1}{10}$ ohm = 0·000002 ohm; it is thus easy to measure with great accuracy extremely small differences between two coils or to determine temperature coëfficients, even though extremely small.

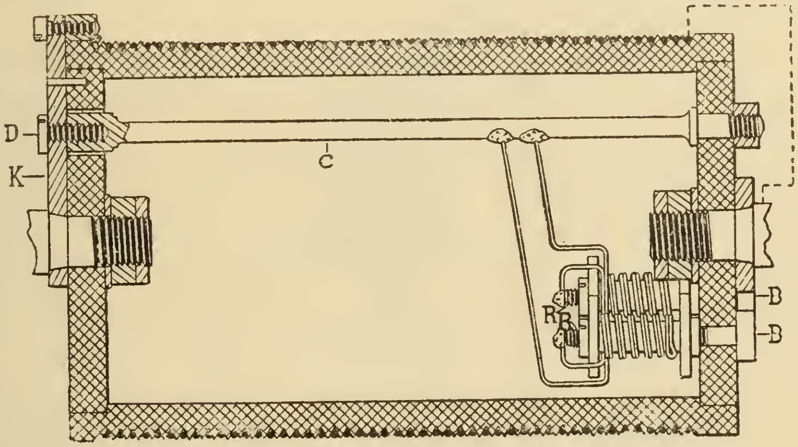


FIG. 7.

The method of arranging the shunts in this apparatus is worthy of notice; they are so placed that their adjustment, by the maker is easy and convenient. Referring to *Fig. 6*, the shunts are each mounted upon rods *R*, screwing into the end blocks *B*; one end of each shunt is soldered to its rod. The other ends of each shunt are soldered to the rod *C*. In adjusting, the right-hand head of the cylinder is slipped out of position, carrying with it the shunts and rod *C*; the shunts are adjusted as accurately as possible and the head slipped back. As the head slips into place the rod *C* shoulders against a heavy copper strap *K*, connecting with the left-hand end of the bridge wire. A copper screw *D* then taps into both the strap *K* and rod *C*, thus making a clean, fresh screw connection between them; a careful measurement of the total resistance is now made, the amount of necessary correction noted and the head again slipped out. A very few trials will suffice to get the desired resistance with great accuracy.

The heavy copper end straps, to which the ends of the bridge wire are soldered, are coned very tightly upon the shafts of the cylinder. These end shafts are of solid copper one-half inch in diameter, and revolve in heavy copper bearings brazed directly to the straps going to the commutating attachment. On the inside of each bearing is formed a massive mercury cup, in which revolves a copper ring $1\frac{3}{8}$ inches in diameter and $\frac{1}{8}$ inch thick; these rings have been sprung upon each end bearing and fit very tightly. Over half a square inch of their surface is always under the surface of the mercury, which is always kept at the same height. The surface of copper contact is so large and the thickness of mercury so small that the resistance at these places is negligable; it is also constant. A sliding brush contact will not answer for work of this kind, as the contact resistance is apt to be variable. In order to prevent the mercury from spreading, by capillary attraction, over the adjacent copper surfaces, each copper ring is clamped, just outside the shaft, between rubber washers recessed and filled with sticky wax. This wax, pressing against the copper, will, it is hoped, aided by the thick bands of lacquer, keep the mercury in its proper place.

Particular attention must be drawn to the fact that every particle of metal forming, in any way, part of the circuit or in contact with it, is of copper in both the commutator and cylindrical bridge with the exception of the wire itself. This is necessary not only to keep the resistance of the circuit small, but also to avoid *thermal currents and contact E. M. F.'s.* In the earlier apparatus referred to in the first part of this paper, it has been impossible to do the highest grade of work without thoroughly wrapping a large part of it in cloths or paper to keep down the thermal currents, and this, despite the fact that about the only metal *except* copper, was in the binding posts; these, however, are sufficient to generate disturbing E. M. F.'s of sufficient magnitude to effectually mask the results desired, and it was seen to be imperatively necessary to get rid of this *entirely.* In the present apparatus the binding posts, connectors, cups, shafts, shunt rods *C* and *K*, the terminal blocks of the shunt coils and all are copper; only the junctions of the wire itself can possibly give trouble, and this, experience has shown, need not be feared in the cylindrical bridge.

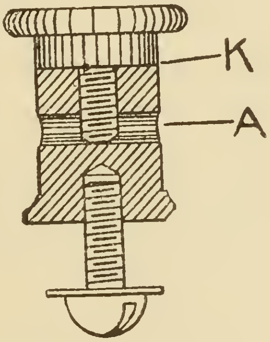


FIG. 8.

It is obvious that by simply replacing *X* and *S*, *Fig. 1*, by negligable resistances we convert the arrangement into the simple Wheatstone's bridge. Hence, in the apparatus in *Fig. 3* we need but to place short, heavy copper wires in place of the standards on each side to enable us to use the device for ordinary work.

Often it is desirable to measure spools of wire quite accurately (say to $\frac{1}{20}$ per cent.), as, for instance, in the adjustment of a high-grade resistance box, where the coils must be as accurate as possible before putting into the set since any adjustment *then* would involve the loosening and re-making of a solid joint and much inconvenience. With this apparatus this work can be done in one-fifth the time necessary with the usual apparatus, and with a more certain accuracy. Since, in such cases, it would not be worth while to solder wire ends to heavy coppers for immersion in the mercury cups, and since, indeed, the accuracy wanted does not require it, binding posts have been provided for this purpose just back of the mercury cups. These posts are of the "double grip" style, designed by Queen & Co. (shown in section in *Fig. 8*), and will catch the finest wires securely, either in the hole *A* or between the surfaces *K*; the resistance of quite heavy copper conductors may thus be measured.

Many results obtained with and showing the performanec of this apparatus might be given. The following, transcribed from one of our laboratory note-books, is sufficient, however, to show the exceedingly high accuracy obtainable. It is the record of a standardization of a coil recently sent to us by one of the large universities for an exact determination of its value. The data, as will be observed, were obtained on four different days, when, of course, minor conditions and the personal equation were likely to be very different.

ELIOTT OHM, NO. 106.

(*a*) October 27, 1892.			
Millimetres to balance, . .	— 358·3	value in ohms, . .	— 0·01250
Temp. of standard (E No. 186),	13°·0 C.	value of standard, . .	0·99675
Temp. of ohm (No. 106), . .	13°·25 C.	value of ohm No. 106,	0·98425
(*b*) October 27, 1892.			
Millimetres to balance, . .	— 355·0	value in ohms, . .	— 0·01239
Temp. of standard (E No. 186),	12°·7 C.	value of standard, .	0·99667
Temperature of ohm No. 106,	13°·3 C.	value of ohm No. 106,	0·98428
(*c*) October 27, 1892.			
Millimetres to balance, . .	— 429·3	value in ohms, . .	— 0·01502
Standard (A), ...	——	value in standard, .	1·00608
Temperature of ohm No. 106,	42°·1 C.	value of ohm No. 106,	0·99106
(*d*) October 27, 1892.			
Millimetres to balance, . .	— 424·8	value in ohms, . .	— 0·01487
Standard (A), ...	——	value of standard, . .	1·00608
Temperature of ohm No. 106,	42°·3 C.	value of ohm No. 106,	0·99121

(*e*) October 28, 1892.

Millimetres to balance, . .	— 171·4	value in ohms, . .	— 0·02091
Standard (A), ...	——	value of standard, . .	1·00608
Temperature of ohm No. 106,	18°·0 C.	value of ohm No. 106,	0·98517

(*f*) October 28, 1892.

Millimetres to balance, . .	— 596·3	value in ohms, . .	— 0·02087
Standard (A), ...	——	value of standard, . .	1·00608
Temperature of ohm No. 106,	18°·1 C.	value of ohm No. 106,	0·98521

(*g*) November 7, 1892.

Millimetres to balance, . .	— 293·9	value in ohms, . .	— 0·01029
Standard (B), ...	——	value of standard, .	0·99588
Temperature of ohm No. 106,	18°·1 C.	value of ohm No. 106,	0·98559

(*h*) November 10, 1892.

Millimetres to balance, . .	— 284·3	value in ohms, . .	— 0·00995
Standard (B), ...	——	value of standard, .	0·99587
Temperature of ohm No. 106,	19°·5 C.	value of ohm No. 106,	0·98592

(*i*) November 10, 1892.

Millimetres to balance, . .	— 284·8	value in ohms, . .	— 0·00997
Standard (B), ...	——	value of standard, .	0·99585
Temperature of ohm No. 106,	19°·3 C.	value of ohm No. 106,	0·98588

ACCURACY OF RESULTS.

Date.	*Test.*	*Value.*	*T—° C.*	*Accuracy of Agreement with Temperature Coëfficient Applied Between.*
October 27, 1892	(*a*)	0·98425	13°·25 C.	
				(*a*) and (*b*) $\frac{1}{500}$ per cent.
October 27, 1892	(*b*)	0·98428	13°·3 C.	
October 28, 1892	(*e*)	0·98517	18°·0 C.	
				(*e*) and (*f*) $\frac{1}{300}$ per cent.
October 28, 1892	(*f*)	0·98521	18°·1 C.	
November 7, 1892	(*g*)	0·98559	18°·1 C.	
				(*g*) and (*h*) $\frac{1}{500}$ per cent.
November 10, 1892	(*h*)	0·98592	19°·5 C.	
November 10, 1892	(*i*)	0·98588	19°·3 C.	(*g*) and (*i*) $\frac{1}{1000}$ per cent.
				(*h*) and (*i*) $\frac{1}{1000}$ per cent.

DETERMINATION OF TEMPERATURE COEFFICIENT.

(1) From (*c*) we have . . . . 0·99106 ohms at 42°·1 C.
From (*e*) we have . . . . 0·98517 ohms at 18°·0 C.

Difference is . . . . 0·00589 ohms for 24°·1 C.

$$\therefore \text{Temperature coëfficient} = \frac{0{\cdot}00589}{24{\cdot}1 \times 0{\cdot}98517} = 0{\cdot}000252$$

(2) From (d) we have . . . . 0·99121 ohms at 42°·3 C.
From (f) we have . . . . 0·98521 ohms at 18°·1 C.

Difference is . . . . 0·00600 ohms at 24°·2 C.

$$\text{Temperature coëfficient} = \frac{0\cdot00060}{24\cdot2 \times 0\cdot98521}\ 0\cdot000252$$

SUMMARY.

Between October 28th and November 7th, the temperature was, at times, very low. This caused the increase noted in (g), (h) and (i) over (e) and (f). The fall between (a), (b) and (e), (f) was due to the heating to which the coil was subjected in (c), (d). This coil, No. 106, was of platinum silver, and this *permanent increase* if subjected to low temperatures and decrease if too high temperature are well-known characteristics of the alloy. The present value of the coil is given by (g), (h), (i): this value holds, providing the limits 12°·0 C. and 25°·0 C. are not exceeded. After noticing the permanent change in resistance above referred to, I wrote to Professor Carhart, who had sent us No. 106, telling him of it and saying that it probably occurred as a result of the heating necessary in getting its temperature coëfficient, but did not give him the coëfficient we had obtained. In his letter of reply, he said: "I meant to tell you not to heat the standard, as we have very carefully determined its coëfficient. It is not over 0·00025, I think." This, as contrasted with our value given above, is a difference of but $\frac{1}{5000}$ per cent., and shows how close work can be done with the apparatus in the hands of different observers in different places at different times.

Since the preceding portion of this paper was written, considerable additional work of the character which has been discussed has been done under my direction, with the previously described, and kindred forms of, apparatus. The results have been even more gratifying than those which have been given.

In connection with the work another new design of the apparatus has been produced which may seem to some to offer points of further advantage. The new design is shown in perspective in *Fig. 9.* As will be noted, the bridge and commutator are here combined in one piece so that the apparatus is complete in itself. The arrangement is, upon

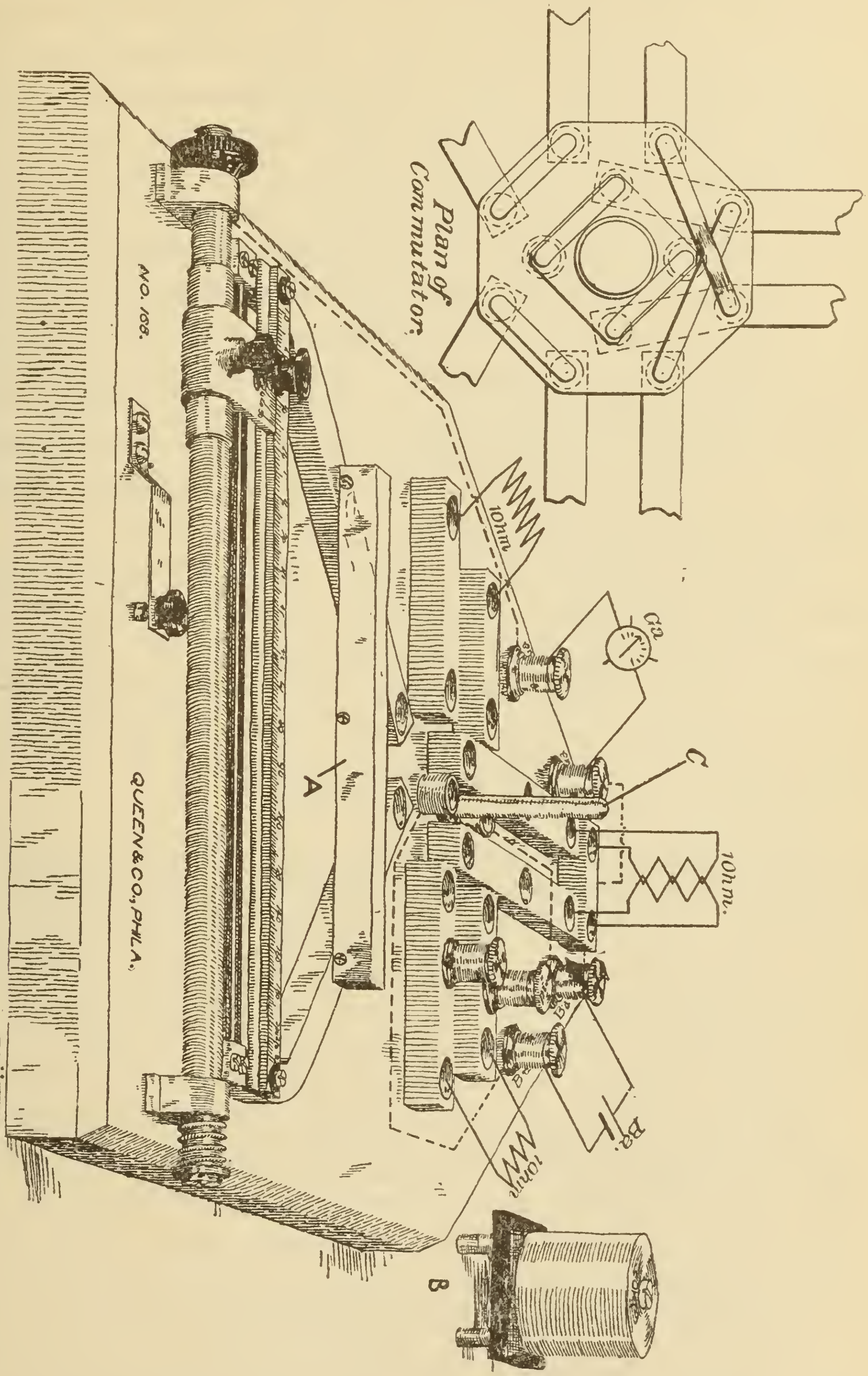


FIG. 9.—Improved bridge for comparing standards of resistance.

the whole, exactly the same as that shown in *Fig. 3*, the principal differences between the two being in compactness and simplicity of construction. The two commutators of *Fig. 3* are so arranged that but *one* movement is required to effect the commutation, instead of two. This commutator, moving upon the rod *C*, really consists of two parts, one fitting upon the other. By using the upper head the whole platform is moved and the coils *X* and *S* (*Fig. 1*) are interchanged. By moving the lower head only, the *battery* alone is commuted, thus enabling us *perfectly* to eliminate all thermal effects. This is a very important matter, as the E. M. F.'s used are all so small that thermal potentials may prove greater than those employed, as was earlier pointed out. *The ability to commute the battery only is, consequently, of vital importance if good results are to be attained.* The pattern shown in *Fig. 3* accomplished this by four movements (*Fig. 5*), as was shown; the new design, therefore, enables us to save two movements.

The two accessory coils *S*, *Fig. 3*, are here mounted in much the same way, but their terminals simply drop into mercury cups instead of being gripped by binding posts. The two coils under comparison are placed at the sides as before; by means of the binding posts a coil may be placed in multiple with the standard in determining the resistance of the bridge wire by the second method.

The bridge wire is permanently a part of the apparatus; it is twenty centimetres long. The slider is provided with a vernier by means of which the wire may be read to one-twentieth millimetre. A very fine adjustment of the slider may be obtained by means of the screw nut attached to the rod upon which the slider usually moves, but to which it may be rigidly clamped if desired. In order to have as low a resistance bridge wire as may be necessary, shunts are used, as in the cylindrical bridge, *Figs. 6* and *7*. The shunt is a wire of suitable size mounted upon a rubber strip and covered by a little zinc box *A*; two copper terminals, to which the shunt is attached, drop into two mercury cups so as to shunt the bridge wire. Different shunts may be used for different ranges of work. Each shunt may have stamped upon it the value of resistance of unit bridge wire division obtained by its use. This mode of varying the resistance of the bridge wire is much superior to the employment of a number of wires which may either be bodily changed or with which may be used an adjustable slider which may be placed so as to run above any particular wire desired. The greatest advantage lies in the fact that using shunts it becomes worth while to work down the bridge wire until it is perfectly uniform in resistance; a shunt will then merely lower its total resistance. If the wires are bodily changed either this large amount of labor must be applied to each one or else a different calibration curve must be used for each wire. Another objection would be the difficulty of always getting the same contact resistances at the ends of the wire; if made with mercury they would be variable, owing to the instability produced by the contacts of the slider.

The apparatus is very simple to make, all the copper work being ordinary market-copper bars one-half inch square and bent into the required shape, the cups being drilled in the bars themselves. It is also very compact, measuring but 11 x 10½ inches over all.

BOOK NOTICES.

Highway Construction. Designed as a text-book and work of reference for all who may be engaged in the location, construction and maintenance of roads, streets and pavements. By Austin T. Byrne, C.E. New York: John Wiley & Son. Pp 685. Price, $5.

At a time when there is so great interest manifested in the highways of our country any work touching upon the subject must command attention, and the author has conferred a service in compiling, so far as possible, data from every available source, digesting and classifying it in such manner as to make this work an encyclopædia for specialists.

Amongst the many good points of the book may be mentioned his list of the literature of the subject from which he drew his inspiration, although we fail to notice in it some of the standard authorities, such as McAdams, McNeill, Telford, the Consular Reports of the State Department on "Streets and Highways in Foreign Countries," 1891, so rich in precedent, as well as the comprehensive compilation published in 1890, by the *Engineering and Building Record*, entitled "Pavements and Roads."

The broad scope of this work is shown at once by an enumeration of its chapter headings, beginning with Pavements and their Materials; Stone, Wood, Asphaltum, Brick, Broken Stone; Miscellaneous: continuing through

Foundations; Resistance to Traction; Location of County Roads; Width and Section; Earth Work—Drainage and Culverts; Bridges; Retaining Walls; Protection Works; Tunnels; Fencing City Streets; Footpaths; Curbs, Gutters; Reconstruction of County Roads; and closing with Maintenance; Trees; Specifications and Contracts; Implements and Prices. There are ninety tables of reference of various kinds and of great value, pertaining to roads. In short, there is hardly anything belonging to the subject that does not appear to be contained in the work in one form or another. It is a fund of knowledge for which the price is no equivalent. The book is simply invaluable and takes rank with its companion, which it resembles in many particulars, edited by Prof. Ira O. Baker, on "Masonary Construction." The publishers are to be congratulated on these two works, and the profession will be benefited by more of the same sort on other specialties.

It is to be regretted, however, that the diagrams are not better, for although they serve their purpose, the appearance of the book, as to its make-up, is marred by the crude and unskilful work in the preparation of many of the cuts (*vide* p. 56, *et al.*). There are a few points upon which we venture to suggest that the author's comments may lead to expensive constructions which may not be justified in practice, *e. g.*, he says; "Wide streets add materially to the commercial prosperity of a city," etc., and "A street which is likely to become a commercial thoroughfare should have a width of not less than 120 feet," etc. (p. 386). We know of very few business thoroughfares so wide as 120 feet. Parks and boulevards may equal and even exceed this width, but we hold that it is not economical to make either a street or road a foot wider than is necessary for traffic, since it adds to the expense of maintenance, increases distances, reduces the taxable or productive areas through which it passes and becomes a burden and often a nuisance instead of a blessing.

There is a ratio between the street and building area which will vary with the character of the business, latitude and physical conditions incident to the city. In general it may be said that the street areas should not exceed 33 per cent. of the total built-up territory, and the widths of the streets should be largely a function of the number, size and character of the vehicles traversing them. In American cities where the sidewalks are frequently used for storing or displaying wares they need to be wider than abroad where such practices are not allowed.

On pp. 66 and 67 are shown two granite blocks intersections differing materially the one from the other, one being fairly good the other bad, but with the same captions, "intersection paved with granite blocks," and having no adjacent description stating their relative merits, neither is there any reference to *intersections* in the index or under pavements where we could expect to find it, but under "*paving at street junctions*," there is a reference to p. 61 where, without a distinctive heading is an allusion to the cuts on pp. 66 and 67 as being alternate designs, one merely affording better foothold. The author has apparently failed to recognize that the weakest point of all rectangular pavements is the *joint in the direction of traffic* which soon becomes rutted by the *wheel*, hence he accepts and states some conclusions which do not give the practical results in the manner of laying the blocks. There is also room for a brief digest of some of the best patents on the subject of various kinds of pavements and modes of laying. On the whole, however, as we have already stated, the book is one which no one interested in the subject can afford to be without, and we can cheerfully commend it to the student, supervisor, engineer or even the taxpayer who may think he "knows it all," but who will find here something not yet dreamed of in his philosophy. L. M. H.

Useful Information and Data for Travellers, Railwaymen and Mechanics. Compiled by T. R. Nichols. Second edition. Chicago: Danks & Co. 1892.

Mr. Nichols has succeeded in crowding in the space of sixty-eight pages of a small pocket book a collection of facts, figures and information about railroad construction and operation, methods of construction and miscellaneous data of value to the mechanic, that ought to serve a useful purpose. The contents of the book is well indexed. As our copy is entitled a second edition, the work would appear to have demonstrated its *raison d'être.* W.

Electricity and Magnetism. Being a series of advanced primers of electricity. By Edwin J. Houston, A. M., etc. New York: The W. J. Johnston Company, Limited, 41 Park Row. London: Whittaker & Co. 1893.

This volume may be considered as an expansion of the admirable series of primers first prepared by the same author for the information of the visitors to the International Electrical Exhibition, held under the auspices of the Franklin Institute in the year 1884. At that time, the general public was practically in dense ignorance of the subject of electricity and its applications, but in the eight years that have elapsed since then, the public has been educated to such an extent that the extremely elementary instruction contained in the original primers, requires to be supplemented by information of a more advanced character.

This information Professor Houston has supplied in the present volume and supplied in his usual happy style.

This volume contains eighteen primers in all, the last one being a review, or "Primer of Primers," which sums up the salient features of the different topics treated. The subjects of the different primers relate to the various sources and phenomena of static and current electricity, and of magnetism, with practical deductions and applications. Atmospheric electricity and the phenomena of the earth's magnetism receive a particularly interesting treatment, and the primers on the electro-magnet, electro-receptive devices and frictional and influence machines are very practical in their scope.

A feature of the work is the abstracts from standard electrical authors at the end of each primer, which generally have reference, and furnish an extension, to some important point in the primer, and at the same time give the reader an introduction to electrical literature.

While the work is primarily intended for popular reading, the care of statement and logical development of principles make it a valuable work for electricians who wish to gain a knowledge of, or to review, the principles upon which the science is based. W.

Franklin Institute.

[*Proceedings of the annual meeting, held Wednesday, Jan. 18, 1893.*]

Hall of the Franklin Institute,
Philadelphia, January 18, 1893.

Mr. Jos. M. Wilson, President, in the chair.

Present, 174 members and thirteen visitors.

Additions to membership since last report, sixteen.

The Secretary presented the annual reports of the Board of Managers, of the several standing committees, of the Chemical and Electrical Sections, and of the Trustees of the Elliott-Cresson Fund, which were duly approved.

The tellers of the annual election, held this day between the hours of 4 and 8 P.M., presented their report, which was accepted, and the tellers were discharged with a vote of thanks.

The President thereupon declared the result of the election, as follows:

For *President*	(to serve one year), . . .	Joseph M. Wilson.
" *Vice-President*	(" three years), . . .	Charles Bullock.
" *Secretary*	(" one year), . . .	Wm. H. Wahl.
" *Treasurer*	(" " "), . . .	Samuel Sartain.
" *Auditor*	(" three years), . . .	Samuel H. Needles.
" "	(in place of Wm. A. Cheyney, deceased), .	Francis Leclere.

For the *Board of Managers* (to serve three years).

Charles H. Banes,
F. Lynwood Garrison,
J. Howard Gibson,
Washington Jones,
Isaac Norris,
Theodore D. Rand,
Stacy Reeves,
Coleman Sellers.

For the *Committee on Science and the Arts* (to serve three years).

Arthur Beardsley,
Hugo Bilgram,
Frank P. Brown,
John H. Cooper,
N. H. Edgerton,
G. M. Eldridge,
F. L. Garrison,
Reuben Haines,
John Hall,
Arthur Kitson,
Edward F. Moody,
E. Alexander Scott,
Coleman Sellers,
H. W. Spangler,
William H. Wahl.

Mr. George D. Burton, of Boston, Mass., read a paper on his system of electric forging, describing the method and special apparatus employed, and illustrating the subject with a large number of interesting specimens of the work produced, and by lantern slides exhibiting the details of the various machines and devices employed. The paper was referred for publication.

Prof. Edwin J. Houston gave a brief sketch of the principle of operation of the gramophone, invented by Mr. Emile Berliner, of Washington, pointing out especially the substantial differences in the record-making process between this apparatus and the phonograph and graphophone. The members were then given the opportunity of hearing the reproduction of a number of musical pieces, recitations, songs, etc., which were rendered with sufficient loudness to be distinctly audible all over the lecture-room, and with remarkable fidelity.

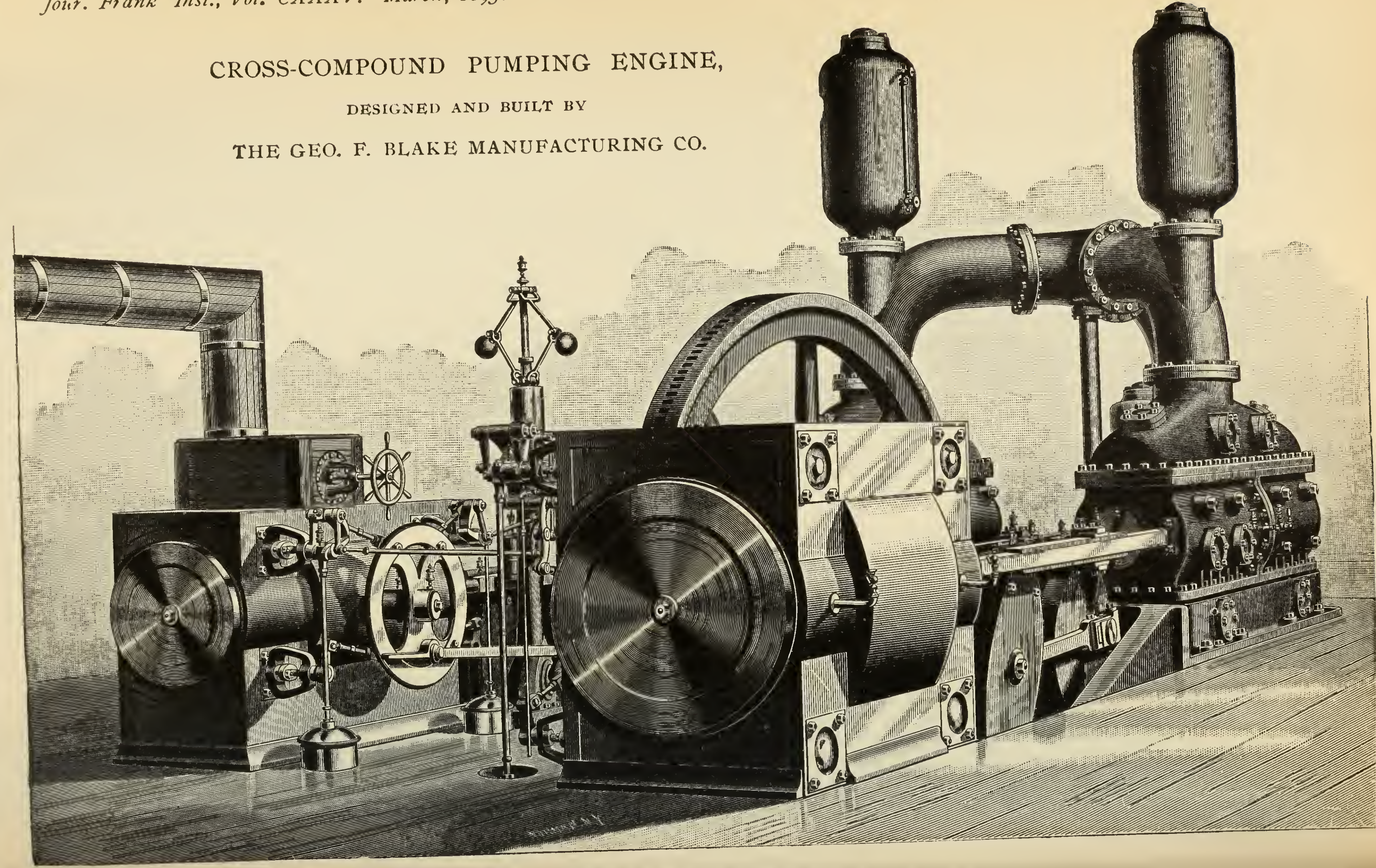
The thanks of the meeting were voted to Mr. Burton and to Mr. Berliner for their interesting contributions.

Adjourned. WM. H. WAHL, *Secretary.*

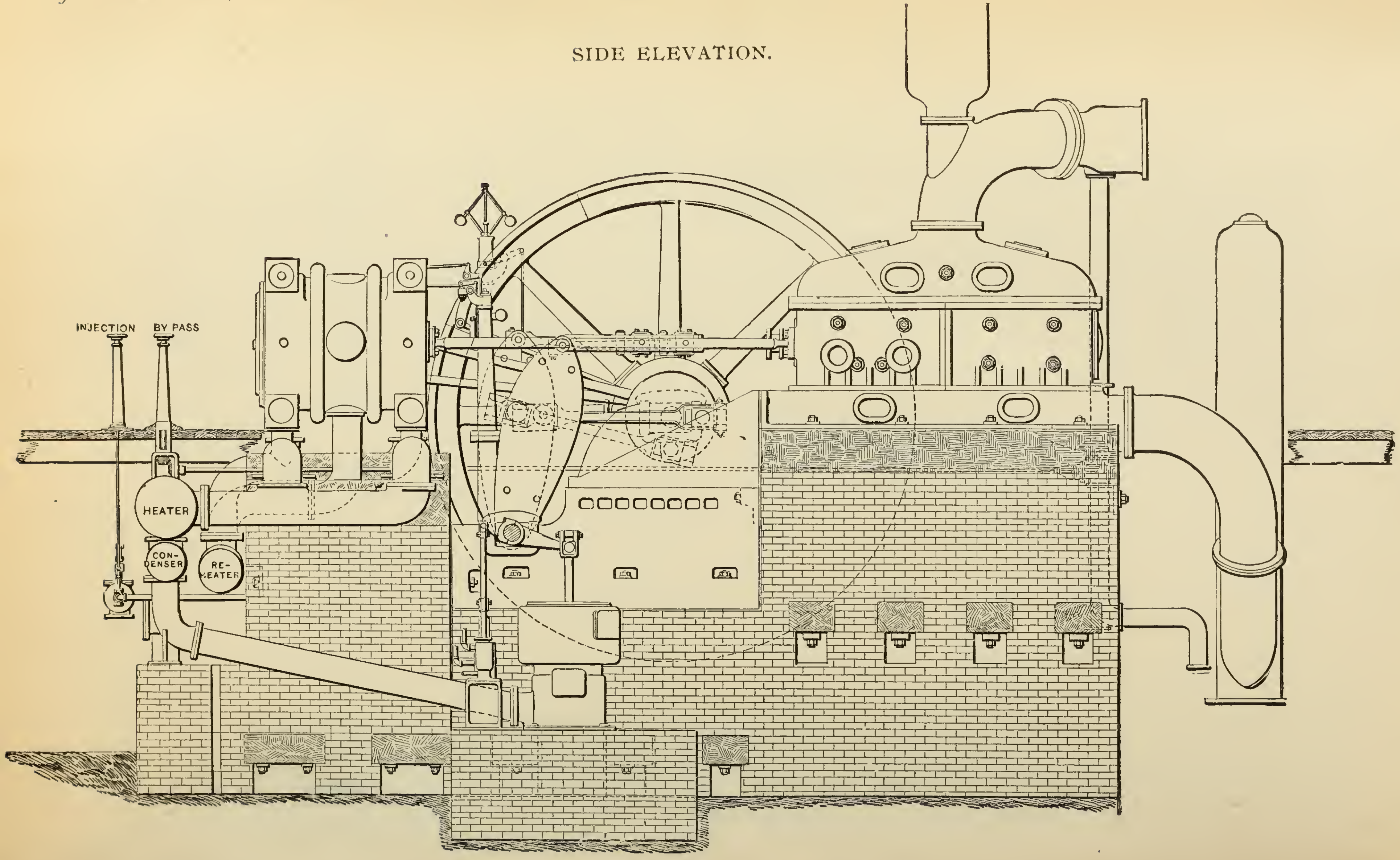
CROSS-COMPOUND PUMPING ENGINE,

DESIGNED AND BUILT BY

THE GEO. F. BLAKE MANUFACTURING CO.



SIDE ELEVATION.



JOURNAL

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FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXXXV. MARCH, 1893. NO. 3

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DUTY TRIAL OF A PUMPING ENGINE, BUILT BY THE GEO. F. BLAKE MANUFACTURING COMPANY.

BY CECIL H. PEABODY, S.B.

In the spring of 1892, the author was requested by The Geo. F. Blake Manufacturing Company to make a duty trial of a pumping engine, designed and built by them for the City Water Works, of Newton, Mass., and located at Newton Upper Falls. The engine had then been running under the normal conditions of regular service for some time, and it, with the boilers, which however were furnished by the company, were in good regular running condition. The test was made solely for the information of the company, and the author considered it desirable that the conditions secured, and the precautions taken, should be such that the performance of the engine during the test could be repeated at pleasure, with this engine or any engine of like size and type.

DESCRIPTION OF THE ENGINE.

The engine was built under the requirements that it should have sufficient capacity to deliver easily 5,000,000 U. S. gallons in twenty-four hours of continuous operation into the reservoir, through a force main 3½ miles long and 20 inches in diameter, against a maximum head, exclusive of friction in the pipes, of 235·25 feet. It should be mentioned, however, that the supply for the city is taken from this main at several points not far distant from the pumping station, by what is known as the direct indirect system.

The specifications required that the duty performed should be the number of pounds of water raised one foot high with a quantity of water evaporated into dry steam, the eqivalent of which shall be 1,100 pounds of water from and at 212° F. Based upon this unit of measurement the builders guaranteed a duty of 115,000,000 foot-pounds of work. It will be seen that the engine, during the test, showed a handsome excess over the guaranteed duty, and that the capacity as indicated by the plunger displacement was satisfactory.

The engine, which is shown in perspective and elevation by *Plates I* and *II*, may be described as of the direct-acting, fly-wheel, cross-compound type, having one high-pressure and one low-pressure steam cylinder with two double-acting inside plunger pumps. Both high and low-pressure cylinders are provided with valve gears of the Corliss type. The valves are closed by vacuum dash-pots with internal communications between the vacuum and cushion pressure, and the action of the gear is smooth and noiseless without clicking or hissing. The steam cylinders are jacketed on the barrels and on the heads, the jackets being cast with the cylinders. The steam for supplying both the cylinders and the high-pressure jacket is brought to the steam chest on top of the high-pressure cylinder; the jacket on that cylinder is in free communication with the steam chest, and the condensation therein is drained away from the bottom of the jacket through a trap; during the test, this condensation was wasted and not allowed for. The loss from this cause, though small, must have been appreciable, and was, of course, against the performance of the engine.

The steam from the high-pressure cylinder exhaust space passed down into the intermediate receiver, which contained a tubular reheater presenting 120 square feet of heating surface, thence up through the low-pressure cylinder jacket and into the low-pressure steam chest. The reheater is supplied with steam under full boiler pressure, and the condensation is returned, under normal conditions, directly to the boiler by a special feed pump driven by the main engine; during the test this return was interrupted, and the steam from the reheater was measured and allowed for. The regular feed water for the boiler is drawn from the hot well and passed through a tubular exhaust steam feed water heater by a feed pump driven by the main engine.

DIMENSIONS OF THE ENGINE.

	Inches.
Diameter of the high-pressure cylinder, ...	21
Diameter of the low-pressure cylinder, ...	42
Diameter of two pump plungers, ...	13½
Diameter of all piston rods, ...	4
Stroke of all pistons and plungers, ...	40
Diameter of one single acting air pump, ...	26
Stroke of same, ...	12
Diameter of single-acting plunger feed pump, ...	4½
Stroke of same, ...	6
Diameter of pump plunger for returning reheater drain to boiler,	2
Stroke of same, ...	6

The diameters of the pump plungers and of the piston rod were calipered and measured. Other dimensions were supplied by the builders.

METHOD OF MAKING THE TRIAL.

The object of this test was to determine the steam and heat consumption of the engine, the power generated in the steam cylinders and exerted by the pump plungers, and the evaporative efficiency of the boiler supplying steam to the engine, and therefrom to find the duty of the engine. No attempt was made to determine the quantity of water pumped, or the slip of the pump. For a boiler test not longer than twelve hours, it was deemed essential that a new fire should be built at the beginning of the test, and that the fire should be drawn at the end of the test; consequently the engine test was, from necessity, begun after the boiler test was started, and it was stopped before the boiler test was ended. It will be shown later how the results of the two tests, which were carried on at the same time, can be united so as to give the duty of the engine based on coal consumption.

The engine and boiler were run for some time under the normal conditions, at full power, before beginning the tests; when all was ready, the engine was run slowly, the fires in the boiler were drawn, and new fires were made with weighed wood and coal; when the fires were well alight, the boiler test was considered to be started. Half an hour after the boiler test was started, the test on the engine was begun; the engine itself was working at full power soon after the time taken for the beginning of the boiler test. The engine test continued for ten hours, but the engine ran at full power up to half an hour of stopping the boiler test, and continued to run nearly at full power till the fires were drawn.

The quantities determined are: the weight of coal (including equivalent of wood for kindling the fires); the weight and temperature of the feed water supplied to the boiler; the speed of the engine; the weight and quality of the steam used by the engine, both in the cylinders and in the reheater between the cylinders; the steam pressure at the boiler, and near the throttle valve of the engine; the weight and temperature of the water drained from the reheater; the power of the steam cylinders and of the pump plungers.

The coal was weighed in an iron barrow, and fired therefrom as required; no coal was allowed on the fire-room floor, which was swept clean. The feed water supplied to the boiler was weighed in a barrel on the engine-room floor, and delivered to a large barrel in the basement, from which the feed pump connected to the engine was supplied during the test. The connection between the feed pump and the hot well was broken before the test began. The barrel in the basement was accurately filled to the same marked height at the beginning and end of the test; a valve in the pipe leading from this barrel to the feed pump was closed at the time of beginning and ending the boiler test, to facilitate this operation. The water level in the boiler, at the beginning of the boiler test, was marked on a wooden scale secured to the water glass on the boiler, and at the end of the test the water level was brought to the same mark. The boiler was making steam at about the same rate at the beginning and end of the test, and, moreover, the boiler made steam so freely and had so large a free water surface, that the apparent level of the water did not change with the rate of evaporation.

The speed of the engine was determined from the engine counter. The boiler undergoing test, supplied steam to the engine only; consequently the total steam supplied to the cylinders and the reheater was determined from the feed water supplied to the boiler during the time of the test on the engine. The level of the water in the barrel in the basement, from which the feed pump drew, was determined and marked at the beginning of the engine test; and in like manner the level in that barrel was determined and marked at the end of the test; the difference between the quantities of water in that barrel at the beginning and end of the engine test was subsequently determined and allowed for. The level of the water in the boiler at the beginning of the engine test was marked on the aforementioned scale attached to the water glass, and the level was brought to the same mark at the end of the engine test. The drain from the reheater, which is ordinarily returned directly to the boiler, was collected and weighed in a barrel, which had been partly filled with cold water to prevent vaporization and loss. When it became necessary to empty this weighing barrel and provide a new supply of cold water, the drain from the reheater was wasted; but these

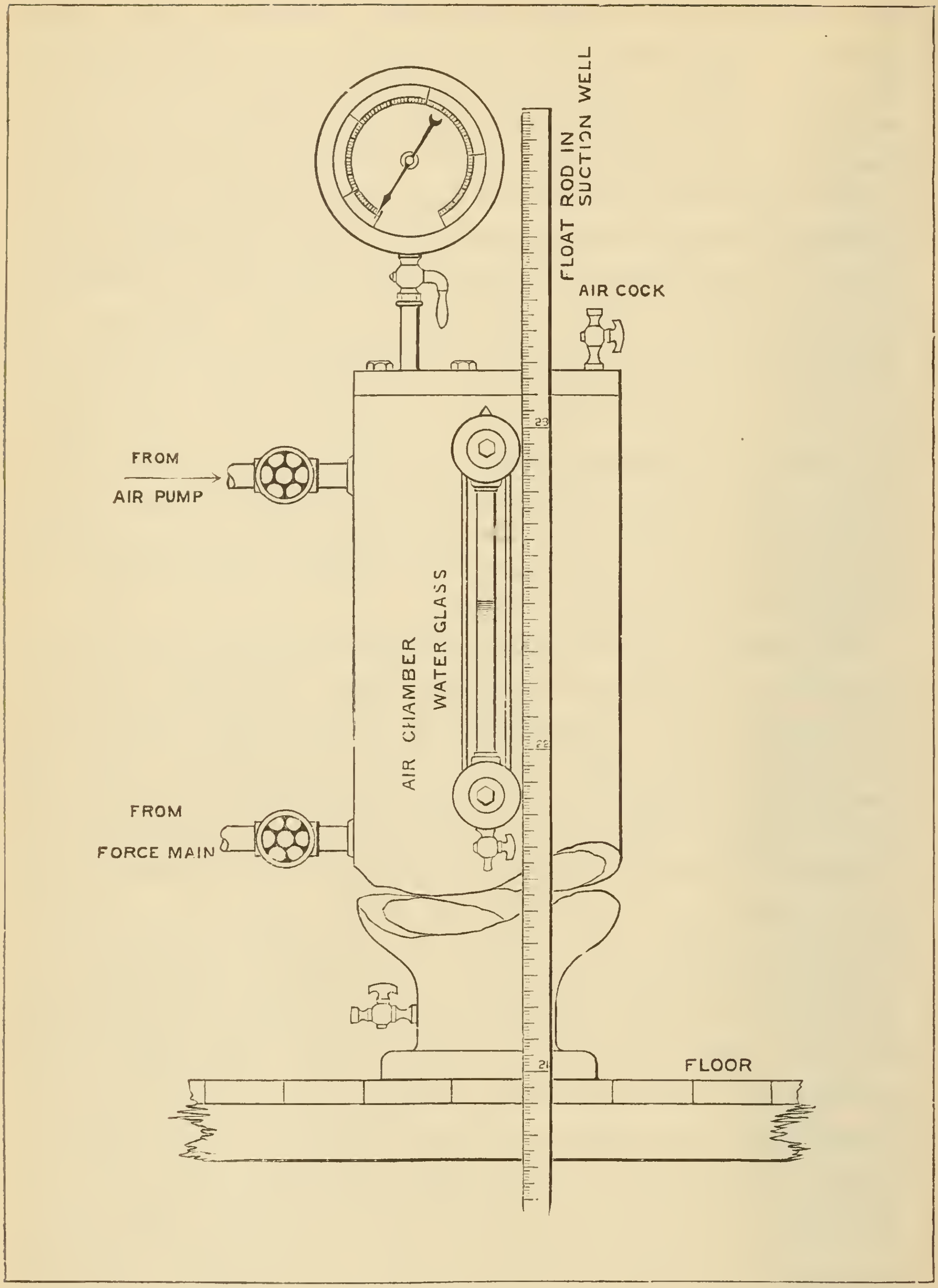

FIG. 1.

times were recorded and allowed for, from the rate of condensation determined from the time when the drain was caught and weighed. The temperature of the water drained from the reheater was taken near the weighing barrel. A previous test (made April 27th) showed a loss of temperature between the barrel and the boiler of 38° F.; the same loss of temperature was assumed for this test.

The quality of the steam supplied to the engine was determined by a calorimeter near the throttle valve. The steam used by the calorimeter was gauged by causing it to flow through an orifice and was allowed for. The steam supplied to the reheater was assumed to have the same quality. The steam in the steam pipe near the boiler was assumed to be dry and saturated.

The pressure at the boiler, near the throttle valve, that in the calorimeter (when in use) and the vacuum were taken by the aid of test gauges. The steam supplied to the reheater was assumed to be under boiler pressure. Readings were taken every fifteen minutes. The pressure of the atmosphere was determined by a mercurial barometer.

The power of the steam cylinders was determined by the aid of indicator diagrams taken every fifteen minutes, all of which were reduced by the aid of planimeters. The power of the pump plungers was determined from the total water column against which the pump worked, not allowing in any way for the friction of foot valve, pump valves or suction main. To determine this water column, use was made of a device shown by *Fig. 1.*

The lower part of the chamber is placed in communication with the forcing main, and the upper part is filled with air; a glass gauge on the side shows the level of the water, and a gauge on the top of the chamber, which is not affected by troublesome jarring or fluctuation of its needle, gives the pressure of the air. The quantity of air in the chamber and the level of the water can be adjusted by aid of an air force pump. A float in the well carries a graduated rod which moves freely near the glass water gauge and allows the depth of the water in the well below the water line in the chamber to be read directly. The mean effective pressure, under which the plungers worked, was taken to be the pressure equivalent of the water column, from the level of the well to the level in the closed chamber, plus the pressure shown by the gauge on the top of this chamber.

All the instruments used during the tests, namely, the scales, indicators, gauges and thermometers, were tested and corrections were applied when necessary. All the apparatus was watched personally by the author, and readings were checked from time to time, and are known to be substantially correct.

OBSERVATIONS, WEIGHTS AND MEASUREMENTS.

The following tables give observations, weights and measurements, taken during the test, together with corrections:

ENGINE RECORD.—(*Date, April 30, 1892.*)

TIME.		COUNTER.		PRESSURE BY GAUGE, IN POUNDS WHERE NOT OTHERWISE STATED.					TEMPERATURE CENTIGRADE.	
H.	M.	Reading.	Diff.	On Boiler.	At Throttle	Vacuum in Inches.	Force Main.	Float Rod in Feet.	Reheater Drain.	Main Feed at Boiler.
10	00	22,191		127·5	124·0	27·2	110	18·54	161·0	46·0
	10		568				109	18·64		
	15	22,759		127·5	123·0	27·0			162·3	46·0
	20		568				109	18·71		
	30	23,327		123·7	122·0	27·0	110	18·80	160·8	46·0
	40		566				110	18·87		
	45	23,893		125·9	123·0	27·0			160·0	46·0
	50		564				108	18·94		
11	00	24,457		124·0	121·5	27·0	109	19·02	159·7	46·2
	10		564				108	19·10		
	15	25,021		124·0	121·0	27·1			160·5	47·0
	20		564				109	19·18		
	30	25,585		124·9	123·0	27·0	109	19·26	161·4	47·1
	40		565				110	19·35		
	45	26,150		125·1	121·5	27·0			160·8	47·0
	50		565				108	19·42		
12	00	26,715		123·9	122·5	27·2	109	19·49	160·8	47·0
	10		564				108	19·67		
	15	27,279		123·1	122·5	27·0			160·8	47·1
	20		564				109	19·54		
	30	27,843		124·0	120·5	27·2	110	19·62	160·6	46·0
	40		563				110	19·70		
	45	28,406		124·7	124·0	27·2			160·3	46·0
	50		565				108	19·75		
1	00	28,971		124·7	124·0	27·1	110	19·84	160·0	45·5
	10		565				110	19·92		
	15	29,536		124·0	122·0	27·1			160·1	47·0
	20		564				110	19·97		
	30	30,100		125·0	121·5	27·1	110	20·05	160·4	47·0
	40		564				111	20·17		
	45	30,664		125·1	121·5	27·1				47·1
	50		564							
2	00	31,228		124·5	124·0	27·0	109	20·25	160·8	46·3
	10		565				108	20·33		
	15	31,793		124·6	122·0	27·2			161·3	46·5
	20		565				110	20·40		
	30	32,358		123·0	121·5	26·9	111	20·46	161·0	47·5
	40		565				109	20·53		
	45	32,923		123·0	122·5	27·0			161·2	46·5
	50		564				108	20·47		

ENGINE RECORD—*Continued.*

TIME.		COUNTER.		PRESSURE BY GAUGE, IN POUNDS WHERE NOT OTHERWISE STATED.					TEMPERATURE CENTIGRADE.	
H.	M.	Reading.	Diff.	On Boiler.	At Throttle	Vacuum in Inches.	Force Main.	Float Rod in Feet.	Reheater Drain.	Main Feed at Boiler.
3	00	33,487		124·5	123·0	27·1	107	20·44	162·0	47·1
	10		565				108	20·48		
	15	34,052		123·0	120·5	27·2			161·7	46·8
	20		565				109	20·48		
	30	34,617		123·5	121·5	27·2	109	20·51	161·9	46·8
	40		565				110	20·57		
	45	35,182		124·1	123·0	27·3			161·8	46·1
	50		567				109	20·65		
4	00	35,749		124·3	123·5	27·1	108	20·70	162·1	47·0
	10		566				108	20·70		
	15	36,315		123·4	122·5	27·2			162·2	46·7
	20		567				107	20·60		
	30	36,882		125·1	124·0	27·4	106	20·65	162·3	47·0
	40		568				108	20·65		
	45	37,450		125·1	123·0	27·4			162·8	46·9
	50		566				105	20·70		
5	00	38,016		125·3	124·5	27·2	109	20·75	163·0	45·5
	10		567				109	20·80		
	15	38,583		125·5	124·0	27·3			162·3	45·0
	20		567				112	20·83		
	30	39,150		125·5	123·5	27·3	109	20·88	163·0	45·5
	40		565				107	20·91		
	45	39,715		126·5	123·0	27·1			162·5	46·1
	50		566				107	20·94		
6	00	40,281		123·1	121·0	27·3	112	20·97	162·8	45·6
	10		566				107	21·00		
	15	40,847		123·0	123·0	27·2			162·2	45·5
	20		566				108	21·05		
	30	41,413		129·0	124·5	27·3	107	21·08	163·5	45·5
	40		565				107	21·09		
	45	41,978		125·7	124·5	27·0			162·5	50·0
	50		566				106	21·13		
7	00	42,544		123·2	123·0	27·3	107	21·17	162·5	48·0
	10		566				107	21·22		
	15	43,110		123·3	121·5	27·4			162·0	48·0
	20		565				107	21·24		
	30	43,675		124·5	122·5	27·5	108	21·07	162·3	47·1
	40		566				107	21·11		
	45	44,241		124·0	124·0	27·4			162·2	47·0
	50		567				107	21·14		
8	00	44,808		125·5	123·5	27·4	106	21·14	161·0	47·0
Totals, ...			22,617	5111·3	5031·0	1114·	6512·	1214·64	6462·4	1911·
Means, ...				124·66	122·7	27·17	108·53	20·244	161·56	46·6
Corrected reading, ...				122·66	119·9	27·07	107·73	8·77 lbs.	161·52	46·6
Pressure of atmosphere, . .				14·8	14·8				322°·7 F.	116° F.
Absolute pressures, ...				137·46	134·7	Pressure on pump, 107·73 + 8·77 = 116·5 lbs.				

INDICATOR DIAGRAMS OF HIGH-PRESSURE STEAM CYLINDER—SCALE 100.

CARD.	HEAD END.		CRANK END.		CUT-OFF IN PER CENT.	
	Area.	Length.	Area.	Length.	Head End.	Crank End.
1	1·84	4·57	2·38	4·58	17·5	23·
2	1·85	4·57	2·35	4·58	18·	23·
3	2·03	4·57	2·30	4·58	20·	22·5
4	2·07	4·58	2·12	4·58	20·	19·
5	2·15	4·58	2·13	4·59	22·5	20·
6	1·98	4·57	2·03	4·58	19·	18·
7	2·13	4·57	2·13	4·59	20·	19·5
8	2·09	4·57	2·11	4·58	21·	19·
9	2·04	4·57	2·02	4·59	20·5	19·5
10	2·10	4·57	2·04	4·58	22·5	19·
11	1·96	4·57	2·14	4·58	19·5	20·
12	2·04	4·57	2·11	4·59	20·	20·
13	2·20	4·57	2·14	4·59	22·5	20·
14	2·15	4·57	2·11	4·59	22·5	20·
15	1·98	4·57	2·02	4·59	19·5	18·
16	2·12	4·59	2·10	4·58	21·	19·
17	1·98	4·57	2·11	4·58	19·5	20·
18	2·09	4·57	2·09	4·59	20·5	19·
19	2·01	4·58	2·09	4·59	20·	19·5
20	2·18	4·57	2·13	4·58	23·	20·
21	1·98	4·58	2·14	4·59	19·	19·5
22	2·26	4·57	2·04	4·60	24·	19·5
23	1·96	4·57	2·06	4·58	19·	20·
24	1·94	4·57	2·02	4·58	19·	19·5
25	1·98	4·57	2·04	4·58	19·	19·
26	2·14	4·58	2·03	4·59	21·	19·5
27	2·16	4·58	2·00	4·59	21·	18·
28	1·97	4·59	2·10	4·58	19·	19·
29	2·04	4·59	2·04	4·59	20·	18·5
30	2·02	4·58	2·11	4·59	19·	18·5
31	2·08	4·57	2·11	4·59	21·	19·
32	2·23	4·57	2·12	4·59	22·	19·
33	2·08	4·57	2·07	4·59	20·	19·
34	2·09	4·59	2·17	4·59	20·5	20·
35	2·13	4·57	2·07	4·59	19·	18·
36	2·11	4·57	2·07	4·60	20·5	19·
37	2·07	4·59	2·07	4·59	20·	19·
38	1·98	4·59	2·05	4·59	20·	20·
39	2·18	4·58	2·06	4·59	21·5	19·
40	2·06	4·59	2·12	4·59	19·5	19·5
41	2·17	4·60	2·11	4·59	20·	18·5
Total, . .	84·62	187·62	86·25	188·06	833·0	799·0
Means, .	2·063	4·57	2·10	4·58	20·3	19.5

INDICATOR DIAGRAMS OF LOW-PRESSURE CYLINDER—SCALE 16.

CARD.	HEAD END.		CRANK END.		CUT-OFF IN PER CENT.	
	Area.	Length.	Area.	Length.	Head End.	Crank End.
1	3·50	4·59	3·73	4·62	23·	23·5
2	3·56	4·59	3·90	4·62	24·	24·
3	3·63	4·60	3·86	4·62	25·	24·5
4	3·63	4·60	3·75	4·62	27·	26·
5	3·60	4·60	3·74	4·62	27·	26·
6	3·65	4·60	3·76	4·62	27·	26·
7	3·56	4·60	3·81	4·63	24·	25·
8	3·58	4·60	3·79	4·62	25·	25·
9	3·58	4·60	3·88	4·62	24·5	25·5
10	3·77	4·61	3·82	4·62	26·5	25·
11	3·77	4·60	3·88	4·62	26·5	25·
12	3·70	4·61	3·92	4·63	25·5	26·5
13	3·70	4·61	3·86	4·62	26·	25·
14	3·79	4·60	3·86	4·61	26·	25·
15	3·73	4·60	3·88	4·62	26·5	25·
16	3·65	4·61	3·86	4·62	25·5	25·
17	3·72	4·61	3·79	4·63	26·	23·
18	3·62	4·61	3·83	4·62	26·	25·
19	3·71	4·62	3·87	4·62	26·	25·
20	3·58	4·60	3·88	4·62	26·	26·
21	3·56	4·61	3·78	4·62	24·	24·
22	3·56	4·60	3·85	4·62	24·5	26·
23	3·61	4·60	3·81	4·62	25·5	24·
24	3·83	4·60	3·74	4·62	26·5	24·
25	3·67	4·61	3·84	4·61	25·5	24·
26	3·75	4·60	3·88	4·61	26·5	25·
27	3·68	4·60	3·93	4·61	24·	26·
28	3·61	4·61	3·81	4·61	23·5	25·
29	3·72	4·61	3·77	4·62	25·5	23·5
30	3·50	4·60	3·75	4·62	27·5	24·5
31	3·57	4·60	3·85	4·61	24·5	24·5
32	3·49	4·59	3·82	4·62	23·	24·
33	3·57	4·59	3·74	4·61	24·	24·
34	3·74	4·60	3·75	4·62	26·	24·
35	3·53	4·60	3·82	4·62	22·5	25·
36	3·60	4·61	3·80	4·62	25·	25·5
37	3·80	4·62	3·69	4·59	25·5	24·5
38	3·59	4·60	3·74	4·62	25·5	24·5
39	3·67	4·61	3·72	4·62	24·	23·5
40	3·62	4·60	3·76	4·62	25·	24·5
41	3·44	4·60	3·75	4·62	23·	24·5
Totals, .	149·14	188·72	156·27	189·35	1034·0	1015·5
Means, .	3·64	4·60	3·81	4·61	25·2	24·8

COAL AND BOILER RECORD.

Time of Firing.	*Wood and Coal. Barrow Full.*	*Barrow Empty.*	*Weight of Coal or Wood.*	*Gauge Pressure on Boiler.*	*Temp. of Feed at Boiler. Cent.*
9·26	356 lbs. 398·5 lbs. } wood.	141·5 141·5	214·5 257·0 } wood.		
	471·5 × 0·4 = coal equivalent of wood = 188·6 lbs.				
9·30	636·5 coal.	236·5	400	130·5	
40					
45	636·5	236·5	400	126·7	48·0
10·00	engine test commenced.			127·5	46·0
15				129·5	46·0
30				123·7	46·0
40					
45	636·5	236·5	400	125·9	46·0
11·00				124·0	46·2
15				124·0	47·0
30				124·9	47·1
35					
45				125·1	47·0
12·00				123·9	47·0
15	636·5	236·5	400	123·1	47·1
20					
30				124·0	46·0
35					
45				124·7	46·0
1·00	636·5	236·5	400	124·7	45·5
15				124·0	47·0
30				125·0	47·0
45				125·1	47·1
2·00	636·5	236·5	400	124·5	46·3
15				124·6	46·5
30				123·0	47·5
45				123·0	46·5
3·00	636·5	236·5	400	124·5	47·1
05					
15				123·0	46·8
30				123·5	46·8
45	636·5	236·5	400	124·1	46·1
4·00				124·3	47·0
4·15				123·4	46·7
30				125·1	47·0
45	636·5	236·5	400	125·1	46·9
5·00				125·3	45·5
10					

COAL AND BOILER RECORD.—(*Continued.*)

Time of Firing.	*Wood and Coal. Barrow Full.*	*Barrow Empty.*	*Weight of Coal or Wood.*	*Gauge Pressure on Boiler.*	*Temp. of Feed at Boiler. Cent.*
15				125·5	45·0
30				125·5	45·5
40					
45				126·5	46·1
6·00	636·5	236·5	400	123·1	45·6
15				123·0	45·5
30				129·0	45·5
45				125·7	50·0
50					
7·00				123·2	48·0
10	636·5	236·5	400		
15				123·3	48·0
30				124·5	47·1
45				124·0	47·0
8·00	engine test ended.			125·5	47·0
15	pump not feeding.			121·0	
30				126·3	49·0
35	636·5	476·0	160·5		
45				123·0	47·0
9·15	stopped.			129·8	
Totals,			4749·1	5868·6	2055·0
Means,				124·87	46·7
			error	2·	
Drawn from grate,	437·5	236·5	201·0	122·87	116·°06F.
Drawn from ash pit,	318·	141·5	176·5	14·8	
			absolute	137·67	

Sample of coal and ashes from grate, ... 8¼ oz. of ash.
5¾ oz. of coal.
14 oz. total.

Sample of coal and ashes from ash pit, ... 6⅝ oz. of ash.
1⅜ oz. of coal.
8 oz. total.

Unburnt coal in ash pit, ... $\frac{11}{64} \times 176{\cdot}5 = 30{\cdot}3$ pounds.
Unburnt coal left on grate, ... $= \frac{23}{56} \times 201 = 82{\cdot}5$ pounds.

Unburnt coal left on grate and in pit, ... = 112·8 pounds.

Ash and cinders in ash pit. . . . . . $= \frac{53}{64} \times 176{\cdot}5 = 146{\cdot}2$ pounds.
Ash and cinders left on grate, . . . $= \frac{33}{56} \times 201 = 118{\cdot}5$ pounds.

Total refuse of ash and cinders, ... 264·7 pounds.

$$\text{Per cent. of ash in coal} = \frac{264{\cdot}7}{100\ (4749{\cdot}1 - 112{\cdot}8)} = 5{\cdot}7 \text{ per cent.}$$

Coal burned, ... 4749·1 — 201 = 4548·1 pounds.

FEED-WATER RECORD.

Total feed water for boiler test, ... 44704·5 pounds.
Total feed water for engine test, ... 38501·5 pounds.

RECORD OF REHEATER DIAMETER.

TIME.	Weight in Pounds, of Barrel, at Beginning.	Weight and Barrel at the End.	Difference or Water Drained.
10·00	1,286		
11·15	*	1,711	425
·25	1,204		
12·30	*	1,592	388
·45	1,202		
1·45	*	1,566	364
2·00	1,206		
3·00	*	1,567	361
3·15	1,109		
4·30	*	1,560	451
4·45	1,104		
6·00	*	1,553	449
6·15	1,106		
7·45	*	1,649	543

For 8 hours 20 minutes, ... 2,981 pounds.
For 10 hours, ... 3,577·2 pounds.

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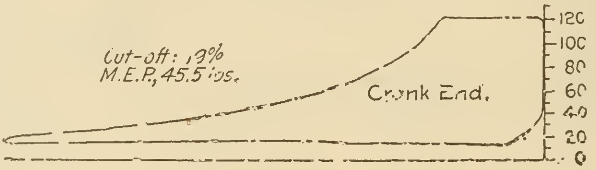
* Water ran to waste during emptying of barrel, for 1 hour 40 minutes.

One set of indicator diagrams, taken at 2·15 and numbered 18 in the table of areas and lengths of the diagrams,

FIG. 2.



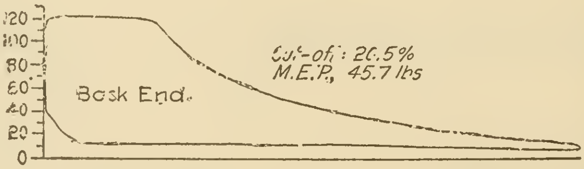


FIG. 3.

is shown by *Figs. 2, 3, 4* and *5*. It will be noticed that the areas and lengths are very nearly the same as the corresponding averages for the entire test; further, it should be stated, that they are fair average samples.

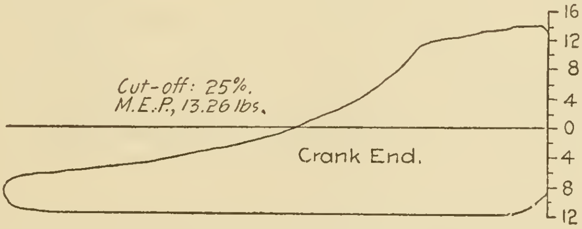
HIGH PRESSURE CYLINDER, CRANK END.

Area	2·09 sq. in.
Length, ...	4·59 in.
M.E.P., ...	45·5 lbs.
Cut-off, ...	19 per cent.

HIGH PRESSURE CYLINDER, BACK END.

Area, ...	2·09 sq. in.
Length, ...	4·57 in.
M.E.P., ...	45·7 lbs.
Cut-off, ...	20·5 per cent.

FIG. 4.



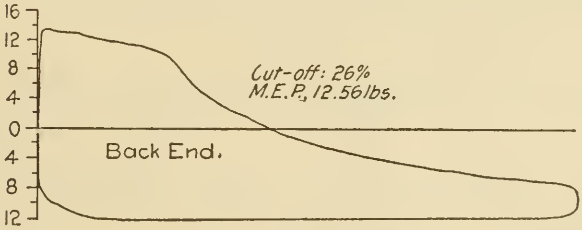


FIG. 5.

LOW-PRESSURE CYLINDER, CRANK END.

Area, ...	3·83 sq. in.
Length, ...	4·62 in.
M.E.P., ...	13·26 lbs.
Cut-off, ...	25 per cent.

LOW-PRESSURE CYLINDER, BACK END.

Area, ...	3·62 sq. in.
Length, ...	4.61 in.
M.E.P., ...	12·56 lbs.
Cut-off, ...	26 per cent.

DATA AND CALCULATIONS.

Boiler Test.

Duration of test, 11 hours 45 minutes, or	11·75 hours.
Average pressure, by gauge, ...	122·87 pounds.
Atmospheric pressure, ...	14·8 pounds.

Average absolute pressure,	137·67 pounds.
Average temperature of feed,	116°·06 F.
Total heat above 32° F., of steam of 137·67 pounds per sq. inch,	[*]1189·1
Heat in water of temperature of 116°·06 F., above 32° F.	84·1
Heat given to every pound of water fed to the boiler, under the assumption that it was evaporated into dry and saturated steam of the boiler pressure, 1189·1 — 84·1 =	1105·0 B.T.U.
Total water fed to the boiler,	44704·5 pounds.
Total coal consumed,	4548·1 pounds.
Water evaporated per pound of coal at boiler pressure and temperature of feed, 44704·5 ÷ 4548·1 =	9·83 pounds.
Ash per pound of coal,	0·057 pound.
Combustible per pound of coal,	0·943 pound.
Water evaporated per pound of combustible at boiler pressure at temperature of feed = 9·83 ÷ 0·943 =	10·42 pounds.
B.T.U., per pound of coal, given to every pound of water fed to the boiler, under the assumption that it was evaporated into dry and saturated steam of the boiler pressure, 9·83 × 1,105 =	10862·15
Equivalent evaporation per pound of coal from and at 212° F. = 1,105 × 9·83 ÷ 965·8 =	11·25 pounds.
Equivalent evaporation per pound of combustible from and at 212° F., 11·25 ÷ 0·943 =	11·93 pounds.
Area of grate,	48·125 feet.
Coal burned per square foot of grate per hour, $= \frac{4548{\cdot}1}{11{\cdot}75 \times 48{\cdot}125}$	8·04 pounds.

Atmospheric Pressure (*Green's Mercurial Barometer*).

Barometer at 10·30 A. M.,	30″·20,	temp. 71° F.
at 3·00 P. M.,	30″·25,	temp. 74° F.
mean,	30″·225,	temp. 72° F.

Reduction to freezing point.[†]

$$\text{Height} = \frac{[1 + s(t - 62)] \times h}{1 + m(t - 32)}$$

where

h = reading of the barometer ;

t = temperature of the attached thermometer ;

m = expansion of mercury for 1° F., taken as 0·0001010 of its length at 32° F.;

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[*] This and other properties of saturated steam are taken from the author's *Tables of the Properties of Saturated Steam.* J. Wiley & Son.

[†] See *Instructions for Voluntary Observers*, United States Department of Agriculture, p. 39, Washington, 1892.

s = expansion of the substance of which the scale is made; for brass s is taken as 0·00001020 of its length (h) at the standard temperature for the scale, viz: 62° F.

Substituting the above values in this formula, we have

$$\text{reduced height} = \frac{30{\cdot}225\,[\,1 + 0{\cdot}00001020\,(72 - 62)\,]}{1 + 0{\cdot}0001010\,(72 - 32)} = 30{\cdot}1$$

The weight of one cubic inch of mercury of the temperature of 32° F. is 0·491 pounds, and consequently the pressure of the atmosphere in this case will be

$$30{\cdot}1 \times 0{\cdot}491 = 14{\cdot}8 \text{ pounds.}$$

Calorimetric Test.

Mean gauge pressure for flow of steam, ...	119·9 pounds.
Pressure of atmosphere, ...	14·8 pounds.
Absolute steam pressure, ...	134·7 pounds.
Diameter of orifice, ...	0·2 inch.
Area of orifice, ...	0·031415 sq. inch.
Total time in which calorimeter was in use, . . .	75 minutes.

Weight of steam through calorimeter is then

$$\frac{75 \times 60 \times 134{\cdot}7 \times 0{\cdot}031415}{70} = \quad 272 \text{ pounds.}$$

Pressure of steam, by gauge, for priming test, . . .	117·9 pounds.
Absolute pressure for do., ...	132·7 pounds.
Pressure of steam in calorimeter, by gauge, ...	11·8 pounds.
Absolute pressure in do., ...	26·6 pounds.
t_s temperature of steam in calorimeter, ...	298°·4 F.
r for pressure 132·7 pounds, ...	868·3 B.T.U.
q for pressure 132·7 pounds, ...	320·0 B.T.U.
λ_c for pressure 26·6 pounds, ...	1156·2 B.T.U.
t_c for pressure 26·6 pounds, ...	243·47
c_p	0·48

The weight of dry steam per pound of the mixture will then be

$$\frac{1156{\cdot}2 + 0{\cdot}48\ [298^{\circ}{\cdot}4 - 243^{\circ}{\cdot}47] - 320}{868{\cdot}3} = 0{\cdot}993 \text{ pounds.}$$

and the priming, ... $(1 - 0{\cdot}993)\,100 = 0{\cdot}7$ per cent.

HORSE-POWERS AND WORK ON THE PUMP PLUNGERS.

Areas of Steam Pistons.

High pressure,	head end, ...	546·361 sq. in.
	crank end (rod 4″), ...	333·795 sq. in.
Low pressure,	head end, ...	1385·44 sq. in.
	crank end (rod 4″), ...	1372·874 sq. in.

Mean Effective Pressures.

High pressure, head end,	45·10 pounds.
crank end,	45·85 pounds.
Low pressure, head end,	12·65 pounds.
crank end,	13·20 pounds.
Revolutions in ten hours,	22,617

Horse-powers of Steam Cylinders.

High-pressure cylinder,

$$\frac{(346{\cdot}361 \times 45{\cdot}10 + 333{\cdot}795 \times 45{\cdot}85) \times 22{,}617 \times 40}{10 \times 60 \times 33{,}000 \times 12} = 117{\cdot}751$$

Low-pressure cylinder,

$$\frac{(1385{\cdot}44 \times 12{\cdot}65 + 1372{\cdot}87 \times 13{\cdot}20) \times 22{,}617 \times 40}{10 \times 60 \times 33{,}000 \times 12} = 135{\cdot}731$$

Total indicated horse-power of steam cylinders, ... 253·482

Work and Horse-power of Pump Plungers.

Area of 13½″ circle,	143·139 sq. in.
One-half area of 4″ circle,	6·283 sq. in.
Mean area of pump plunger,	136·856 sq. in.
Pressure per square inch, 8·77 + 107·73,	116·50 pounds.
Revolutions in ten hours,	22,617.

Work on Plungers for Ten Hours.

$$22{,}617 \times 116{\cdot}5 \times 136{\cdot}856 \times 4 \times \tfrac{40}{12} = 4{,}807{,}990{,}000 \text{ foot-pounds.}$$

Horse-power of pump plungers,

$$\frac{4{,}807{,}990{,}000}{10 \times 60 \times 33{,}000} = \ldots\; 242{\cdot}8$$

Efficiency of mechanism, ... $= \dfrac{242{\cdot}8}{253{\cdot}5} = 0{\cdot}958$

Friction of engine, ... 4·2 per cent.

Displacement of Pump Plungers for Twenty-four Hours.

Revolutions per minute, ... $= \dfrac{22{,}617}{600} = 37{\cdot}695$

$$\text{Displacement} = \frac{136{\cdot}856 \times 40 \times 4 \times 24 \times 60 \times 37{\cdot}695}{231} = 5{,}144{,}675 \text{ gallons.}$$

British Thermal Units (B.T.U.) used by the Engine, etc.

Temp. of feed at the boiler during the boiler test,	116°·06 F.
Temp. of feed at the boiler during engine test,	116°·00 F.
Average absolute steam pressure at the throttle during engine test,	134·7
Heat, *r*, of vaporization of steam of the above pressure (above 32° F.),	867·4 B.T.U.

Heat of the liquid q, corresponding to the pressure 134·7 absolute, above 32° F.,	321·2 B.T.U.
Heat, q_0, of water of 116° F. above 32° F.,	84 B.T.U.
Feed water supplied to boiler during engine test,	38501·5 pounds.
Steam used by calorimeter,	272 pounds.
Steam used by engine in cylinders and reheater,	38229·5 pounds.
Steam used in reheater,	3577·2 pounds.
Weight of mixture passing through steam cylinders,	34652·3 pounds.
Temp. of reheater return at the boiler, 323–38, =	285° F.
Average absolute steam pressure at the boiler during engine test,	137·46 pounds.
Heat, r_1, of vaporization of steam of the above pressure (above 32° F.,) =	866·2 B.T.U.
Heat, q_1, of liquid corresponding to the steam pressure of 137·46 pounds, absolute (above 32° F.)	322·9 B.T.U.
Heat, q_2, of water of 285° F. (above 32° F.),	245·4

The thermal units passing through the steam cylinders will then be

$$34652{\cdot}3\,[0{\cdot}993 \times 867{\cdot}4 + 321{\cdot}2 - 84] = \quad \ldots\ldots \quad 38{,}065{,}550$$

The thermal units passing through the reheater will be

$$3577{\cdot}2\,[0{\cdot}993 \times 866{\cdot}2 + 322{\cdot}9 - 254{\cdot}4] = \quad \ldots\ldots \quad 3{,}321{,}788$$

Total B.T.U. used during engine test, ... 41,387,338

B.T.U. used by engine per pound of coal = 9·83 × 1,105 = ... 10,862

Duties.

Work on pump plungers for ten hours, . 4,807,990,000 foot-pounds.

Heat used by the engine in ten hours, ... 41,387,338 B.T.U.

Coal required by the engine in ten hours,

$$\frac{41{,}387{,}338}{10{,}862} = \ldots\ldots \quad 3{,}833 \text{ pounds.}$$

Mixture of steam and water used by the engine in ten hours, ... 38229·5 pounds.

The duties as expressed in the various ways used in practice, will then be

(1) Per 1,000,000 B.T.U.:

$$\frac{4{,}807{,}990{,}000 \times 1{,}000{,}000}{41{,}387{,}338} = 116{,}170{,}000 \text{ foot-pounds.}$$

(2) Per 1,062,380 B.T.U., or per 1,100 pounds of steam at 212° F., as per basis in Newton Specifications:

$$\frac{4{,}807{,}990{,}000 \times 1{,}062{,}380}{41{,}387{,}338} = 123{,}420{,}000 \text{ foot-pounds.}$$

(3) Per 100 pounds of coal:

Steam pressure at the boiler, absolute. . . . . 137·46 pounds.
B.T.U. per pound of steam (above 32° F.,) of this pressure, ... 1,189
Temperature of feed water at the boiler, ... 116° F.
Heat of liquid (above 32° F.), corresponding . . . 84 B.T.U.
Temperature of reheater drain at the boiler, ... 285° F.
Heat of liquid (above 32° F.), corresponding, ... 254·4 B.T.U.
B.T.U. supplied by boiler to steam delivered to the steam cylinders, 34652·3 × (1,189 — 84) = 34652·3 × 1,105 = ... 38,290,792
B.T.U. supplied by boiler to steam delivered to the reheater, 3577·2 × (1,189 — 2544 = 3577·2 × 934·6 = ... 3,343,251
Total B.T.U. supplied by boiler to steam passing through cylinders and reheater, ... 41,634,043
Heat developed per pound of steam during the boiler test, ... 1,105 B.T.U.
B.T.U. per pound of coal, ... 10,862
Coal used in ten hours,

$$\frac{41,634,043}{10,862} = \ldots\ldots\ 3,833 \text{ pounds.}$$

Then the duty will be

$$\frac{4,807,990,000 \times 100}{3,833} = 125,400,000, \text{ foot-pounds.}$$

(4) Per 100 pounds of coal calculated upon the assumption that one pound of coal is required to evaporate every ten pounds of water fed to the boiler:

Water fed to boiler, ... 38229·5

$$\frac{4,807,990,000 \times 100}{3,824} = 125,762,490 \text{ foot-pounds.}$$

Economy of Engine.

Steam used in cylinders and reheater in ten hours, 38229·5 pounds.
Coal required by the engine for ten hours, . . . 3,833 pounds.
B.T.U. used by the engine in ten hours, ... 41,387,338
Steam per horse-power per hour,

$$\frac{38229{\cdot}5}{10 \times 253{\cdot}5} = \ldots\ldots\ 15{\cdot}08 \text{ pounds.}$$

Coal per horse-power per hour,

$$\frac{3,833}{10 \times 253{\cdot}5} = \ldots\ldots\ 1{\cdot}51 \text{ pounds}$$

B.T.U. per horse-power per minute,

$$\frac{41,387,338}{10 \times 60 \times 253{\cdot}5} = \ldots\ldots\ 272$$

At the time of the test no provision was made for taking the temperature of the feed water near the engine. Subsequent observations showed a loss of 13° F. between the engine and the boiler, when the engine was running under the same conditions. The probable temperature of the feed water during the test was 116° + 13° = 129° F.; the reheater drain near the engine had a temperature during the test of 322°·7 F. The duty of the engine, calculated from the heat supplied to the engine and rejected by the engine, may be stated as follows:

CALCULATIONS BASED UPON THE HEAT SUPPLIED TO AND RETURNED BY THE ENGINE.

Temperature of feed water at engine, ...	129° F.
Temperature of reheater drain at engine, ...	322°·7 F.
Heat of liquid of temperature 129° F. (above 32°), . . .	97°·1 F.
Heat of liquid of temperature 322°·7 F. (above 32°), . .	292°·8 F.

Substituting the above values in the formula already used, we have

B.T.U. per pound of steam passing through the steam cylinders, (0·993 × 867·4 + 321·2 — 97·1) = ...	1,085·4
B.T.U. per pound of steam passing through the reheater, (0·993 × 866·2 × 322·9 — 292°·8 F.) = ...	890·2

And the B.T.U. used by the engine,

In the steam cylinders, 34652·3 × 1085·4 = ...	37,611,607
In the reheater, 3577·2 × 890·2 = ...	3,184,423
Total B.T.U. used by the engine, ...	40,796,030

B.T.U. per horse-power of steam cylinders per minute,

$$\frac{40,796,030}{600 \times 253{\cdot}482} = \ldots\ldots\ldots \quad 268$$

B.T.U. per horse-power of pump cylinders per minute,

$$\frac{40,796,030}{600 \times 242{\cdot}8} = \ldots\ldots\ldots \quad 280$$

Duty per 1,000,000 B.T.U.,

$$\frac{4,807,990,000}{40,796,030} = \ldots\ldots 117,850,000 \text{ foot-pounds.}$$

Duty on the Newton basis,

$$\frac{4,807,990,000}{40,796,030} \times 1,062,380 = 125,200,000 \text{ foot-pounds.}$$

The results of the test, together with a few of the principal data, are assembled in the following table:

Boiler Test:

Duration,	11 hours 45 minutes.
Temperature of feed water,	116·°06 F.
Pressure of steam by gauge,	122·87 pounds.
Pressure of the atmosphere,	14·8 pounds.
Water evaporated from temperature of feed water, into dry steam under boiler pressure, per pound of coal,	9·83 pounds.
Water evaporated (as above) per pound of combustible, allowing 5·7 per cent. ash,	10·42 pounds.
Equivalent evaporation from and at 212° F., per pound of coal,	11·25 pounds.
Equivalent evaporation from and at 212° F., per pound of combustible,	11·93 pounds.
Coal burned per square foot of grate per hour,	8·04 pounds.

Calorimeter Test:

Priming, moisture in steam,	0·7 per cent.

Engine Test:

Duration,	10 hours.
Average revolutions per minute,	37·695
Steam pressure at boiler by gauge,	122·66 pounds.
Steam pressure at throttle,	119·9 pounds.
Vacuum,	27·1 inches.
Pressure of the atmosphere,	14·8 pounds.
Cut-off high-pressure cylinder,	20 per cent
Cut-off low-pressure cylinder,	25 per cent.
Effective pressure exerted by plungers,	116·5 pounds.
Indicated horse-power, high-pressure cylinder,	117·75
Indicated horse-power, low-pressure cylinder,	135·73
Indicated horse-power of engine,	253·48
Steam per horse-power per hour,	15·08 pounds.
B.T.U., per horse-power per minute,	272
Coal per horse-power per hour,	1·51 pounds.
Horse-power of pump plungers,	242·8
Efficiency of mechanisms,	0·958
Friction,	4·2 per cent.
Duty on basis of 1,000,000 B.T.U.,	116,170,000
Duty on Newton basis,	123,420,000
Displacement of pump plungers for twenty-four hours, not allowing for slip,	5,144,675 gals.

The duty of the engine, in the assembled results, is given (1) on the basis of 1,000,000 B.T.U., which is recommended by a committee of the American Society of Mechanical Engineers, and (2) on the basis prescribed by the specifications under which the engine was built, namely, the equivalent of 1,100 pounds of water from and at 212° F.

While it is believed that the numerous and varying standards of pump performance, all known as *duty*, are responsible for much disagreement and misunderstanding, it is thought that, for purposes of comparison, it is well to give the duty of this engine referred to two other standards in common use.

They are:

Duty on basis of 100 pounds of coal, . .	125,400,000 foot-pounds.
Duty on 100 pounds of coal, calculated on the assumption that one pound of coal is required to evaporate ten pounds of water fed to the boiler, . .	125,762,490 foot-pounds.

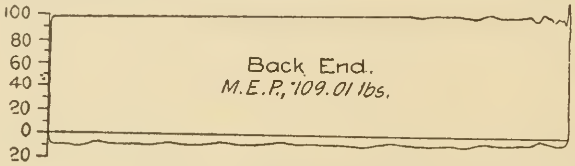
This last method is evidently entirely arbitrary and highly artificial; it appears to have the merit of giving a high record.

In comparing tests on different engines, the convenient, and probably the fairest way, is to use pressures and temperatures taken at or near the engine, thereby eliminating the question of the good or bad economy of the boiler and of the losses of pressure and temperature in the steam pipe and in the boiler feed pipe. A like strict interpretation of the performance of a boiler requires that the temperatures and pressures shall be taken at or near the boiler, and the application of both of these rules in practice would remove the responsibility of the losses due to the conveyance of steam and water alike from the engine and the boiler-maker and transfer it to the owner, where it may in some cases belong. The makers of this engine have thought best to disregard this small, though appreciable disadvantage, in order to give more nearly its commercial value. For purposes of comparison with other engines, the following results have been calculated from the heat supplied to and returned by the engine:

Duty per 1,000,000 B.T.U., ...	117,850,000 foot-pounds.
Duty on the Newton basis, ...	125,200,000 foot-pounds.

Though forming no part of the trial, and not used in reducing the results of the test, the indicator diagrams, shown by *Figs. 6* and *7*, and taken by Mr. Albert F. Hall, the Constructing Engineer of The George F. Blake Manufacturing Company, may be of interest. They were taken with a Thompson indicator on a short one-inch pipe, with a straight-way valve on the pipe and the indicator cock wide open. The engine at the time was making thirty-eight revolutions per minute, and was in general under very nearly the same conditions as at the time of the trial here reported.

FIG. 6.



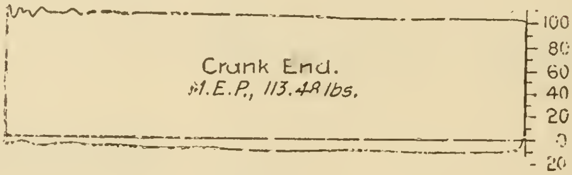


FIG. 7.

BACK END.

Scale 100.	JUNE 11, 1892, 10.40 A. M.
Area,	4·84 sq. in.
Length,	4·44 sq. in.
M.E.P.,	109·01 lbs.

CRANK END.

Scale 100.	11 A. M.
Area,	5·05 sq. in.
Length,	4·45 in.
M.E.P.,	113·48 lbs.

During the entire test the engine ran smoothly and regularly with the same attention that it would receive in good ordinary practice. The regularity of the steam pressure, the suction and the pressure on the pump, and of the work of the steam pistons is shown in the recorded results.

MANGANESE STEEL.

By Henry M. Howe.

[*A lecture delivered before the Franklin Institute, February 20, 1892.*]

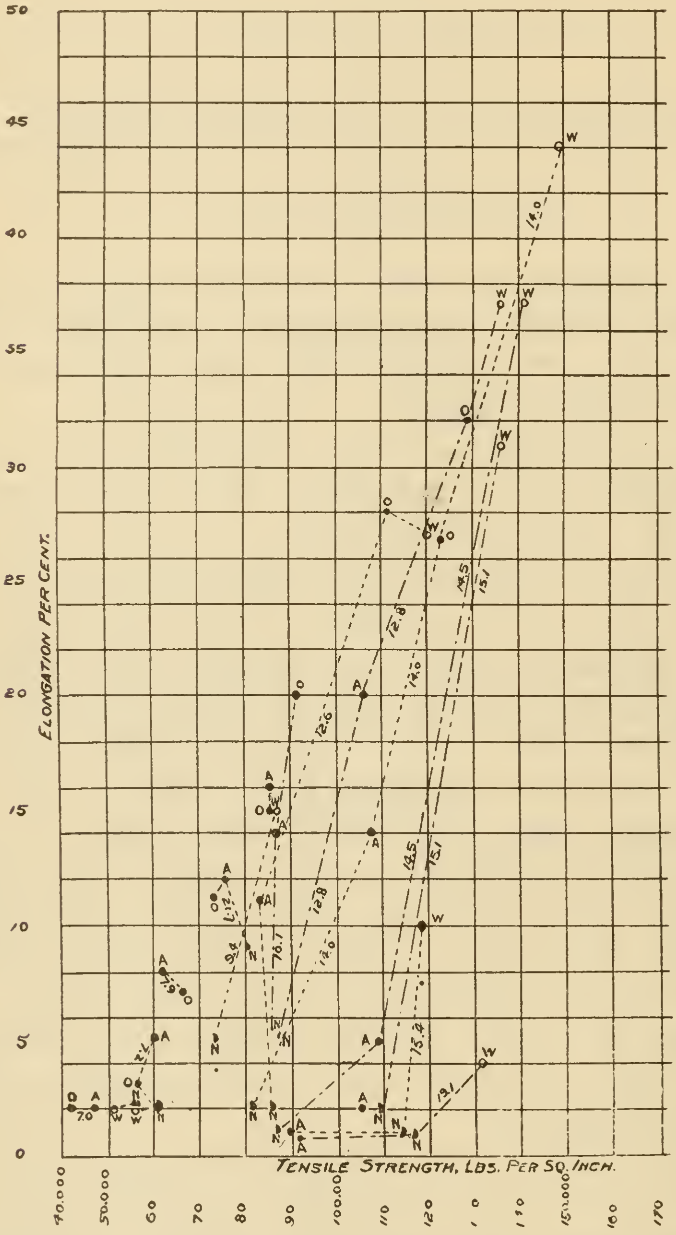
[*Concluded from p. 128.*]

Speaking roughly, we may say that water toughening increases the ductility of manganese steel some fivefold, and occasionally even tenfold; while often at the same time doubling the tensile strength.

In *Fig. 9*, I attempt to show simultaneously how the strength and ductility of manganese steel both increase as we hasten the cooling of the metal; in other words, that the faster we cool it, the stronger and more ductile we find it. Each of the several lines here drawn gives the tensile strength (as abscissa), and the elongation (as ordinate) of pieces of manganese steel cooled at different rates, but in all other respects alike. The semi-circles with the letter N by them, as before, represent the metal in its natural or slowly cooled state; the black circles show the same properties in the suddenly cooled material, the letter A indicating that the metal has been cooled suddenly by a blast of air; the letter O that it has been cooled by plunging in oil; and the letter W that it has been cooled by quenching in water. Let us confine our attention to manganese steel containing from nine per cent. to fifteen per cent. of manganese.

As before, we see that the increase of elongation is much greater than that of tensile strength; in short, the sudden cooling is more markedly a toughening than a strengthening. Next, we note that, in general, the more sudden the cooling, the greater the strength and the elongation. Air cooling, the least rapid, gives the spots next above those of the natural state; oil cooling, next in order of rapidity, gives the next higher spots, while water cooling, the most rapid of all, gives in general the highest spots of all.

Next, what is truly remarkable, that in many cases these lines are nearly straight and parallel from end to end, show-



TENSILE PROPERTIES OF MANGANESE-STEEL.

W = Water-toughened Manganese-Steel
O = Oil " "
A = Air " "
N = Natural state
Figures give percentage of Manganese.

FIG. 9.

ing that the ratio of increase of strength to increase of ductility is nearly constant for varying accelerations of the rate of cooling, and that this ratio is the same, roughly speaking, for manganese steel of different compositions. This certainly seems to indicate that the increase of strength and of ductility are, in the main, due to one and the same ulterior cause. It may be that sudden cooling prevents some change which occurs during undisturbed slow cooling, some change which requires a considerable length of time, and which weakens the metal and lessens its ductility: that at a high temperature the metal assumes a condition which, if preserved by sudden cooling, assures strength and ductility to the cooled metal; while if we cool it slowly, some slow change, decomposition, re-composition or re-arrangement occurs, yielding a relatively weak and brittle substance.

But this explanation may be very far wrong, and, if it be right, we certainly do not know what the nature of the supposed change is. A change in the chemical condition of the carbon has been traced to sudden cooling; but this change does not readily explain matters. Sudden cooling changes most of the carbon of carbon steel from the "non-hardening" to the "hardening" state; and the hardness and brittleness of suddenly cooled carbon steel are usually attributed to the presence of this hardening carbon. In slowly cooled manganese steel the carbon exists in both the hardening and the non-hardening state; sudden cooling increases the proportion of hardening carbon, a change which would be expected to make the metal more brittle, instead of very much more ductile as it actually becomes.

I have thus far spoken of the effect of the rate of cooling on the ductility and strength of manganese steel. But the temperature from which sudden cooling occurs also affects these properties; and in general we may say that the higher the temperature, provided it does not rise above moderate whiteness, from which the metal is suddenly cooled, the stronger and more ductile will it be. In short, violence of cooling, both as regards the rate of cooling and the range of temperature passed through, strengthen the material and increase its ductility.

But here a caution. Pieces of a very ductile material may themselves be locally brittle, locally incapable of enduring much distortion without rupture; pieces of a strong material may themselves be relatively weak. Notch a piece of cloth, and you may easily rip it across, though, if unnotched and twisted up into a rope, it would hold five tons. Nick a bar of steel, and a light blow will break it; file away the sides of the nick, and round and smooth the surface there, and you will find the remaining metal still strong. Thus, a crack causes the material to yield to trifling stress, by concentrating that stress into a limited region.

Now, we all know how easy it is to crack common steel when we harden it by plunging it into water while red-hot. And we know that these cracks are caused by the difference between the rates at which outside and inside cool.

The outside cools rapidly, and hence tends to contract rapidly; the inside cools much less rapidly; hence it contracts less rapidly, and thus opposes the effort of the outside to contract, and to reach the dimensions which it would naturally have at the existing temperature. The resistance of the inside thus, in effect, violently stretches the outside, and may stretch it so far as to crack it.

We all know that pieces whose shape causes great and sudden differences between the rate of cooling and contraction of different parts, and especially of adjoining parts; that is to say, pieces of suddenly and greatly varying thickness, are especially liable to crack in quenching.

Much the same holds true of manganese steel, though in an incomparatively smaller degree. While the metal is so ductile as to endure without cracking the distortion due to rapid cooling, yet extremely violent cooling, though it may give to the material itself its greatest strength and ductility, may yet, in case of castings whose shape or size favors cracking to an unusual degree, cause slight surface cracks, which, if they be not removed, may in themselves locally lessen the strength and ductility. Hence, the piece which has thus been very violently quenched may be likened to a piece of copper which has been nicked; the material is extremely ductile, but there is a local defect, which locally impairs ductility, and so weakens the piece as a whole, just as a weak link weakens the chain as a whole.

Hence it may be best, especially in treating thick pieces of cast manganese steel of irregular section and greatly varying thickness, to cool at a moderate rate, as for instance, by exposing to a blast of cold air, or by repeatedly dipping into water and drawing out again into the air. Naturally, this is especially true of unforged castings whose ductility, and hence whose power of resisting the temporary distortion arising during violent cooling, cannot be expected to equal that of forged pieces. Indeed, I have never known even the most violent cooling to injure forged pieces thus.

Forging.—In heating ingots of manganese steel of usual composition prior to forging them, their temperature must be raised very gradually. The metal conducts heat so slowly that, if exposed when cold to a high temperature, the outside becomes extremely hot, and hence expands greatly, while the interior remains almost cold. The fast expanding outside thus stretches the slowly expanding interior, and may stretch it so much as to crack it. Obviously, it is far better never to allow the ingot to cool, but to place it while still hot with the initial heat of casting, in a hot furnace, and simply leave it there till its interior is well solidified.

Once the material has been forged, however, it may be reheated much more suddenly, without danger of cracking.

For forging, the metal is brought to a light red heat, and at first *saddened;* that is, made compact with light blows; thenceforth it may be struck heavily. But the hardness which it shows when cold persists even at bright redness, and more work, that is to say more and heavier blows, are needed in forging it than most steel requires. For those familiar with working very hard steel, the whole may be summed up by saying that manganese steel behaves in forging like carbon steel containing about 1·25 per cent. or even 1·50 per cent. of carbon.

Manganese steel may be rolled hot into sheets as thin as No. 18 gauge, 0·049 inch, without special difficulty; and it has been rolled hot to No. 28 gauge, 0·014 inch, but with difficulty, for very frequent annealing is needed. It has been rolled cold into much thinner sheets, but it hardens quickly in cold rolling, and must be annealed often.

It has been drawn into wire, 0·0105 inch thick, or of No. 31 B. W. G., No. 30 American wire gauge.

Machining.—Manganese steel of usual composition, while unalterably hard, is yet not so intensely hard that we cannot cut it. For cutting it in lathe or planer, the hardest of carbon or chrome tool steel should be used, and the cutting tools should be made as hard as fire and water will make them. Tools made of Mushet's and other self-hardening steel do not cut it readily, as they lose their edge by "slipping." Of course, the cuts must be very light, and the feed very slow. Exact comparative data are not at hand; but such information as I have indicates that it takes about four times as long to machine manganese steel as common carbon steel. This of course does not mean that it costs four times as much.

In general, it is important to bring the metal while hot as closely as possible to the desired shape, so that but little machining may be needed. It may be shaped by drop forging, hydraulic forging and other special means. It may often be cut advantageously when hot by means of a circular saw, as for instance in removing sinking heads.

In some cases cold rolling and other forms of cold working may be applied to manganese steel, in lieu of machining. For, while it certainly does not work as easily when cold as common soft steel, yet its disadvantage in this respect seems much less than in cutting by means of common steel tools.

In many cases, too, it may be punched or pressed cold to shape. When only a little of the metal is to be removed, manganese steel may be ground advantageously with an emery wheel. No special precautions are needed, beyond running the wheel rather slowly, as in grinding hardened steel. It costs more to grind manganese steel than to grind carbon steel when unhardened, but decidedly less than to grind hardened carbon steel.

Uses.—Let us next consider the actual and prospective uses of manganese steel.

Its most important single use is for the pins which hold the links of dredgers of the elevator or bucket class, some 4,000 of these pins having been made in the last two months of which I have advices. For these pins a strong and at least moderately tough material is needed, and at the same time one that resists abrasion well, as the sand and grit between the pin and the link in which it turns cut sharply. *Fig. 10* shows how much better manganese steel resists abrasion under these conditions than the carbon steel with which it competed. The manganese-steel pin, that which is least worn, has endured more than thrice as much use as its neighbor.*

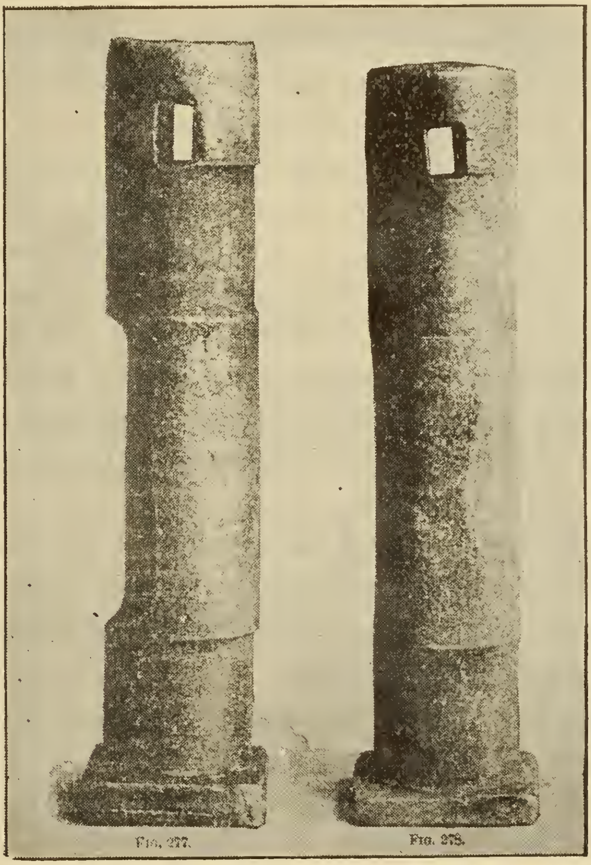


Fig. 10.

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* Since this lecture was read manganese steel dredger pins at Belfast have shown like remarkable endurance, wearing only one-tenth as fast as carbon-steels pins simultaneously used.

In other cases of which I have late reports, equally remarkable results have been reached. At Preston, in England, a full set of manganese-steel pins, after working for eighteen months in sand and gravel, had worn away only about one-eighth of an inch, or only about one-eighth as fast as common steel pins. Manganese-steel dredger pins at Hull, England, are reported as wearing about one-sixth as fast as those of common steel.

Manganese-steel plough shares are reported as wearing six or seven times as long as chilled cast-iron shares. This is rather surprising, considering that the chilled cast iron is certainly harder than manganese steel.

The side plates of the Blake crusher, those between which the jaw plays, when made of manganese steel, have shown great resistance to abrasion. These particular plates are seven-eighths of an inch thick. When made of hard carbon steel, they were worn out in two months; in crushing granite, when made of manganese steel, they were worn away only one-fourth of an inch in ten and one-half months. In other classes of crushing machinery, it has given excellent results.

Other fairly established uses are for the links of chain elevators, and for certain parts of safes. For the latter a material which can neither be drilled nor broken seems to offer exceptional advantages.

Of the many prospective uses of manganese steel I will notice but two, for armor plate and for car wheels.

Manganese-steel armor plates two inches thick have been tested under the conditions of actual warfare. From these tests it is calculated that, in order to offer the same resistance as a manganese-steel plate, a wrought-iron plate would have to be seventy-seven per cent. thicker, and a carbon steel plate forty-eight per cent. thicker.

We cannot yet tell whether manganese steel in very thick plates, such as are used for the sides of war ships, would behave as well as it did in these trials; but they certainly seem to commend it for the light plates with which vessels' decks are armored, and for the light shields which protect the gunners.

For railway car wheels we need a material which, like manganese steel, is so hard that it will not wear away under the friction of the brake-shoe; and yet is so tough that it will not break when it hammers under full load and at full speed against frogs and crossings.

Twenty-two manganese-steel wheels, thirty inches in diameter, on one of the New England railroads, ran from 131,499 to 188,179 miles, or on an average 168,453 miles, before the first turning.

This is nearly seven times the average mileage of chilled cast-iron wheels on this particular road, where the conditions are very trying owing to frequent stops, and the consequent frequent application of the brake. The mileage of these manganese-steel wheels is nearly six times the reported average life (29,074 miles) of cast-iron wheels on the Boston and Albany Railroad. The general belief is that chilled cast-iron passenger wheels, thirty-three inches in diameter, run on an average 60,000 miles before removal; which is about one-third the mileage of these manganese-steel wheels before their first turning.

The mileage of composite or steel-tired wheels is much greater than that of chilled cast-iron wheels, though the steel tire of the composite wheel is very much softer than the cast iron. That of 720 steel-tired wheels on the Boston and Albany Railroad was 111,804 miles before the first turning; the average mileage of these manganese-steel wheels is thus fifty-one per cent. greater than that of these composite wheels before their first turning.

The first cost of the manganese-steel wheel, which is a simple casting, is much below that of the composite wheel. The cost of the wheelage, or wheel service, consists mainly of the first cost of the wheel and of the interest on this first cost. Calculations which I have made, but with which I will not to-night trouble you, show that the manganese-steel wheel is likely to be much cheaper per 1,000 miles run, than the composite wheel.

I believe that the manganese-steel wheel is not only incomparably safer than the chilled cast-iron wheel, but, all things considered, really decidedly safer than the composite wheel.*

Its enormous and extremely constant electric resistance, coupled with its cheapness, as compared with German silver and platinoid, should give manganese steel important applications in electrical engineering.

RESISTANCE TO SHIP'S MOTION: A NATURAL LAW NEWLY DISCOVERED.

By F. M. F. Cazin.

How natural, how uncomplicated, how simple and beautiful does the sail-boat glide along on the waters, that reflect the azure color of space and the shady tints of its rivals—the clouds.

There is a power moving boat and clouds. And there is a resistance to the movement of the one and the others, that is overcome by such power, the former yielding to the latter.

Do scientists at this great age of intellect and invention possess the faculty of precisely and intelligently measuring the resistance just spoken of?

In all of his weak moments in life the engineer takes refuge to his pocket book, in which there is gathered the wisdom of ages. Let us see what these treasures of knowledge in mechanics and engineering tell us on the subject of resistance to ship's motion.

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* A widely-circulated statement of the number of steel tires broken on the railroads of the German Empire in the years 1884 to 1889, inclusive, reports many manganese-steel tires as breaking. But the term "manganese steel," as here unjustifiably used, refers to a wholly different material from that described in this paper; indeed, to a true carbon steel merely containing a little more manganese than usual, but I believe never more than two per cent.; certainly nothing like the percentage of manganese which would entitle it to be classed with the manganese steel forming the subject of this paper. Some of this pseudo-manganese steel, lately examined, contained only 0·60 per cent. of manganese.

John W. Nystrom's book specifies the resistance to the movement of ship as follows (p. 449):[*]

$$R = 2{\cdot}858\, \mathfrak{M}^2 \left[Ms \left(0{\cdot}9 \sqrt{sin^3 a} + 0{\cdot}1 \sqrt{sin^3 b} \right) + \frac{A\, k}{\sqrt[4]{L}} \right]$$

R signifying the resistance to the ship's motion in pounds.
Ms signifying the transverse major section of immersed part of ship.
a signifying the mean angle of resistance to the vessel moving in water.
b signifying the mean angle of delivery of the aft-displacement.
$\mathfrak{M}$ signifying the speed in knots per hour.
A area (surface) of the immersed hull.
k coëfficient of friction in pounds per square foot of the immersed surface (*A*) of the vessel.
L length of vessel in loadwater line.

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[*] John W. Nystrom, C.E., states (p. 448, ed. 1880), that this and other equations relating to the parabolic construction of ships (primarily based on resistance to ship's motion) are based on his equation No. 1.

$$\beta = b \left[1 - \frac{y^n}{l^3} \right]^9$$

for "any ordinate at distance y from M^s.," but that when developed into combinations with the form of ship "this fundamental value becomes a very complicated affair, which required *a separate treatise on ship-building for proper explanation*." In fact, Nystrom's equation is originally based and built up on the fundamental values for resistance to immersed motion, as they were universally accepted, and as they were stated by Weisbach, (*Pocket Manual*) by Rankine (*Applied Mechanics*, p. 598), and W. C. Unwin, (*Encyl. Brit.*, 9th ed., "Hydro-Mechanics," p. 545), when identical symbols are used for identical values, in the equation

$$R = a\,.\,\delta\,.\,M^s \frac{v^2}{2g}$$

these three authorities yet differing one from the other, by Weisbach expressing by a ($= \xi$) a coëfficient (unknown) of form or obstacle, and Unwin expressing by a (K) the "ratio of the plate (face of solid) to the opening of pipe (transverse section of water jet), and Rankine expressing by a (K) a coefficient (unknown) of form. And Nystrom, not acquiescing in such interpretation of either of the three authorities, substitutes for the value a the two values a and b for the "mean angles of resistance (fore) to the vessel moving in the water" and "of delivery (aft)."

And I find

$$\frac{A\,k}{\sqrt[4]{L}}$$

to be used for measuring the effect of friction, and the coëfficient k therein to be assumed as varying between 0·003 and 0·020 or as 1 : 6 . 6 . . .

The valuation of resistance to submerged motion thus expressed rests on a fundamental assumption, which is best and most opportunely expressed in the words of a master of generally acknowledged authority in theoretical mechanics, viz: Prof. Julius Weisbach, he states:

"Though we cannot specify the value of these resistances *a priori*, we may nevertheless assume, on account of the great similarity of conditions with the *percussion* resulting from *isolated jets*, that at least the general law for *percussion by an unlimited quantity of water* does not vary from the law for the *percussion* resulting *from isolated jets*."*

But this assumption has given very little satisfaction to those theoretical mechanicians, including Weisbach himself, who undertook the task of evolving its consequences for either theoretical or practical purposes. Text books of natural philosophy, mechanics and nautics remained in consequence singularly deficient in their statements regarding the *resistance to relative movement of solid and medium*, some omitting altogether to mention the subject, others treating it with superficialty only.

The writer's individual persistency to go to the bottom of the question had nought to do with nautics. A concurrent question for which nowhere a satisfactory solution could be found had propounded itself, namely, the question:

With what velocity would the different particles of disintegrated metallic ore fall in water? Practice told, that different particles fell with different velocities, but the savants, who in volumes of learned reasoning had undertaken to solve this question, had all started from an assumption that appeared on investigation to be untenable, and from a therefrom resulting valuation, such as here above stated, and for which an intelligent or adequate demonstration was not available. And as a consequence they as well as mechanicians, who cultivated other familiar fields of original research, arrived all at the conclusion, that their results were unsatisfactory. And yet the question at issue seemed otherwise to be an extremely simple one. The force of gravitation (weight), that caused the mineral particle to fall was known in each given case. Had it not been for the resistance to the solid's (fall) motion in the water, (medium) all the particles would have fallen with the same identical velocity ($= v$) as

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* Art. 537, vol. 1, pp. 1179–80, 5th ed., revised in 1875 by Gustav Herrmann, Professor at the Polytechnical Institute at Aachen (Aix-le-Chapelle).

$$v = \sqrt{2 g S}$$

g, being twice the distance all matter on earth will pass, when free to fall (in vacuo), in the first second of such fall (toward the centre of the earth).

S, being the total distance of fall (head) under acceleration of gravity.

What this resistance (R) to motion of solid in submersion really be, and what influence in consequence it produced in varying (for different solids) their velocity of fall in submersion, was the main question therefore in this matter, as it is the main question in nautics and navigation.

One learned authority (P. von Rittinger), standing high in an honored public professional office in Austria had written volumes* on this question, and as a main result confessed, that a mere theoretical development of laws for motion in submersion be insufficient for establishing a theoretical foundation to the art of mineral dressing, but that experimental coëfficients be required for completing such foundation. And another learned authority (von Sparre†), of equally high professional office in Prussia found Rittinger's results to be erroneous. And yet neither of the two doubted the correctness of the fundamental assumption, as it is laid down in Weisbach's, Rankine's and Unwin's expressions, as quoted, nor did they doubt the sufficiency of these expressions, for building thereon an attempt on their part to solve the problem before them. But, when von Sparre, the critic, attempted on his part to really solve the problem, employing only a different method of construction on the same foundation,* he arrived at a conclusion, which he stated as follows: "That these results (von Sparre's) are so complicated that their expression in correct values is impossible."†

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* *Lehrbuch der Aufbereitung*, also *Erfahrungen*.

† *Contributions to the Theories of Mineral Dressing.*

That both these savants failed in their attempt to evolve satisfactory results, was evidently caused by the absence of a correct and complete measurement of the resistance to the movement of a solid in a liquid medium, this is of a simple, intelligible valuation of such resistance, that would hold equally good, whether it be applied to the particle of rock, when operated with on a jigger, or whether it be applied to the ocean-going steamer for finding the precise power that would propel it at a stated speed.

The resistance experienced by both is of the same nature and character, though the power causing the particle of rock to fall is its gravitation, while the steamer has to employ energy set free in combustion, and modified into kinetic energy for bringing about her movement. And the purpose of research is in the one case the ascertaining of comparative velocities of fall in submersion, and in the other case it is the ascertaining of not only the precise value of resistance experienced and consequent power to be applied to produce movement, but also of the most rational method of applying power for such purpose.

It might therefore be presumed, that what the savants dealing with particles of rock had failed to find or to develop, would surely be made clear in the hand-books for nautics and navigation, in the service of which so many sturdy human intellects have been at work. But the crop of information that could be gathered in nautical literature proved of even less really scientific value than that possessed by the researches made by metallurgists. If the latter had discussed the valuation of resistance to motion in a medium, because what value they found therefor in general mechanics did not answer their purpose, mariners had remained contented, and had not proven themselves inquisitive beyond what could be read in their text books to the extent to cause the sole inquiry ever seriously attempted, the one mentioned on the following pages to terminate in an advice to experiment in all given cases with the specified model of the ship to be built.

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* "The mathematics may be compared to a mill of exquisite workmanship, which grinds your stuff to any degree of fineness, but nevertheless what you get out depends on what you put in." Prof. Huxley. Compare F. A. P. Barnard, *The Metric System*, ed. 1872, p. 100.

† Page 9 of *Beitraege zur Theorie der Erz-Aufbereitung*.

All of what nautics and navigation possess and use in the premises at this date is based on the assumption, as so clearly stated by Weisbach, of similarity of conditions between the effect of the water jet striking under pressure of head an opposed solid face, and the effect of the great mass of water striking the moving ship. But the same as the metallurgists, so those learned in nautics failed to prove mathematically the correctness as well as the extent of such similarity, or the real cause, on which such similarity rests, or the true nature of the conditions as they exist. And, although I shrink back from stating it, the true value for the effect of the water jet itself seemed but vaguely and even erroneously defined.

It is on the assumption of *percussion* by the medium, that angles of bow (a) and of stern (b), the transverse major section (Ms) and the area of surface (A) and friction measured thereby (k), besides constructive length of ship (L), are made conditional and contributive to the valuation of resistance to ship's motion. And yet I find that since Morin, in 1833, had presented to l'Académie de Paris (t. iii) his *Nouvelles Expériences sur le Frottement*, the scientists of the world had acquiesced in the following facts:

(1) Friction (its effect) is proportional to pressure.

(2) Pressure considered, friction (its effect with smooth faces) is *not* proportional to surface being in contact.

(3) Friction is *not* proportional to, but independent of, velocity of contact movement.

From these facts it appeared, that whatever valuation there had been given to friction by

$$\frac{A\ k}{\sqrt[4]{L}}$$

without accounting for pressure (weight) but qualified by surface (A) and length of body (L) must be erroneous, rendering consequently the entire solution of resistance to motion in submersion (as thereby qualified) erroneous.

From these facts it seemed to be indicated, that, with weight accounted for, friction as its product would already have found its consideration, so much so, as neither surface nor velocity as conditional to friction appeared to be of any influence beyond what *weight* constituted as a condition to friction; and when considering solids with smooth faces, relative motion of solid (smooth faced) and liquid medium appeared not to require a contributive valuation for friction at all, because between a wetted surface of a smooth-faced solid and the liquid mass there is surely no friction or resistance in excess of what the moving parts of the liquid mass itself exercise on one another, and what there is of this, would evidently be included under the caption of head resistance and under that of the assumed condition thereto, viz: viscosity, if such values should really appear as conditional and essential.

If thus it appeared indicated, that the value of friction and of surface be subordinate to the value for weight, experiments made in a supplementary way to those of Morin, proved that *form* (shape) *of face* in the solid (fore and aft) remained *as such* without influence on the resistance to relative motion, but that the medium (water, air, etc.) itself makes correction in all cases, where the form of the solid does not conform to the most favorable conditions for minimal resistance to relative motion, by adding of its own to the moving (relatively) volume, which added volume participates in the solid's relative movement, the resulting lines of the moving mass thereby conforming to those of the medium's molecular division lines.

If a solid with smooth surface and a form closely following the lines of the medium's molecular division be considered, the consideration of both *friction* and *form of face* may therefore be omitted, as long as *weight* be considered. And in case the form of moving solid does not so conform, it appears to be the total relatively moving volume, in part solid and in part of medium, respectively, such total volume's weight, which properly comes into consideration.

What then appears to be really conditional to the measurement of resistance to relative motion of medium and solid, is properly represented by *velocity*, *weight* and *volume* of both solid and medium.

Nevertheless it appeared, that none of the scientists, working in the interests of the technical branches as mentioned, had as yet abandoned a valuation based on the erroneous coëfficients for friction, surface and face, a fact easily ascertained from existing technical literature, from which I shall quote a few specimens only.

In 1869, the British Association for the Promotion of Scientific Research appointed a committee to "inquire into the state of existing knowledge on propulsion and other features of ship's behavior." The committee's attempt to arrive at a precise measurement of the resistance to the ship's motion by the water proved so entirely unsatisfactory in its results, that W. Froude deemed it to be in mitigation of their ostensible failure, to propose in an appendix to the committee's report the substitution for all theoretical measurement of an experimental value, being obtained in each practical case occurring, by experimenting with the ship's model.

In 1873, the *Annual of the Royal School of Architecture and Marine Engineering* (p. 92) as a *résumé* of the report just mentioned and of Froude's appendix thereto makes the following statement:

"The resistance opposing the motion of any vessel is of two kinds—surface friction, and what is commonly called direct head resistance. The former of these is caused by the friction of the water against the vessel's surface, whereby it is partly thrown into small eddies and partly dragged along after the vessel in the form of 'wake.' This resistance may for the present be supposed to vary with the square of the speed, and in comparison of similar vessels of different sizes, with the immersed area, *i. e.*, with the square of the dimension. Neither of these assumptions, as has been shown by Mr. Froude, is quite correct, but we will presently point out how, in deducing the resistance of a ship from that of a model, the error involved may be allowed for. If we take R to denote the resistance due to surface friction, l the dimension (length, say) v the velocity of any vessel, we may express the above algebraically by the formula

$$R = l^2 \times v^2$$

"The head resistance is caused partly by the distortion of the particles of water or viscosity, and partly by the production of waves. The former of these causes may be taken practically to vary, as $l^2 v^2$, when the vessels are not of very small dimensions, and may thus be considered to form part of R; it is by the latter, however, that the chief element of this part of resistance is formed, every vessel being accompanied by a wave having its crest near the bow and stern, and also by a series of subsidiary waves due to the inequalities in the form of the vessel's lines."

In 1885, Prof. R. H. Thurston, of Cornell University, when writing on "The Limit of Speed in Ocean Travel," specified the resistance to the ship's motion as follows:

"The resistance of a steamship or other vessel consists of two principal points:

(*a*) "The effort required to overcome the friction of the water on its wetted surface.

(*b*) "The force expended in producing the waves, that are seen arising about every ship in motion."

And the same author further specifies the two values by him given as conditioning the total value for resistance to relative motion by medium and solid, as follows:

(1) "The friction of hull is found to be very nearly proportional to the area of wetted surface.

(2) "The nearer the form of the ship approaches that of a hemisphere, the less must be the resistance due to friction, and between the latter shape and that elongated form,

which gives minimum head resistance, there must be some intermediate form, which will give the least total resistance.

(3) "The power demanded to propel any vessel at ordinary speed varies as the square of her length nearly, or as the area of the transverse major section and as the cube of the speed."

Besides the values for transverse major section—mean angle of resistance resulting from shape fore and aft, and surface as conditional to friction, the explanations here quoted introduce such values as: viscosity and waves.

Wolfgang von Goethe has Mephistopheles instruct Faust's pupil, that when the true conception is wanting, when he be unable to form a correct idea, to invent a new word to cover the case, which, with superficial humanity, would answer the same purpose, and as well, as a correct understanding would. The word "viscosity" (viscidity, stickiness, slabbiness) has so far answered just such a purpose. Just what value it represents in mechanics nobody has ever defined. It has had to stand for an unknown quantity.

Molecular adhesion lines, wave lines as peculiar to water will appropriately assist the nautical constructor to so construct the ship's bottom, that she conforms in her lines to those indicated by the water's natural (molecular) division lines, the most perfect construction being such, with which the ship's bottom does not drag along with it, when moving, a quantity of water, as if it were a part of the ship itself, either in front of her bow or in her wake. The further the ship's form is from such perfection, the greater will be the addition to the moving volume, and the resistance to the ship's motion will be increased, which is demonstrated by daily experience.

When "waves" result from the movement of the ship, their real cause is either in the ship's inadequate form, this is a form not conforming with the water's molecular division lines, or in the inadequate application of propelling power. Such part of the propelling power as causes waves on the surface, is lost as cause for progressive motion, a fact that is practically demonstrated by action and effect comparatively of paddle-wheel and screw.

Such considerations as those stated on the preceding pages resulted in an attempt on my part to improve on the present teachings in applied mechanics, nautics, etc., that I had come to consider as erroneous, by substituting for indefinite, complicated and merely comparative values such others, as would be definite, concrete, simple and fully intelligent.

But I find that the attempt has brought me into conflict with those, who defend the contents of their text books as unimpeachable. Thus the ungrateful *rôle* of the reformer is imposed upon me, of which I cannot otherwise successfully acquit myself than by sound argument and precise, intelligent expression.

To capture the good-will of professionals it might be well to minutely describe the slow process of freeing oneself from the blinding influence exercised by preconceived notions and the equally slow evolution of new or different conception, but the great value of time in this hurrying age forbids the attempt.

I have to be contented, therefore, with a clear statement of what I claim to be true and a law of nature and with a concise argument in support of the claim, this is of my new method for measuring the effects of the movement of a volume of stable quantity and form in or relative to a liquid or fluid medium.

The following then are the newly proposed dogmas in theoretical and applied mechanics and in natural philosophy, nautics, aëronautics, dynamic metallurgy, astronomy, etc.; as by the writer proposed with all of their consequences and in plain view of the recognized, fundamental principle, that nought need be considered as true, but for which proof can be rendered from facts critically observed and repeatable in nature and by methodical, logically correct conclusions derived therefrom.*

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* Compare: DeGavarelle, *A Protest*, 2d ed., p. 39. "What may be Known and What Not." New York: Polytechnical News Company, 28 Lafayette Place.

SIX NEW THESES IN MECHANICS.

The following six theses then express the new teaching:

(1) A solid moving in submersion a distance (d) equal to its own length, when measured in the direction of motion, displaces of the medium in inverse direction and for the distance of its own length (of travel) a volume ($= B$) equal to its own immersed or submerged volume, and when so moving any other distance (of travel), the solid moves the volume B of the medium in inverse direction of its own motion for the total distance of such travel.

(2) A ship progressing at any stated velocity per second causes the movement in inverse direction within every such second of a quantity of water being equal to

$$D = \frac{B}{d} \,.\, v \text{ metric tons.}$$

B signifying the ship's immersed volume or buoyancy in cubic metres.

d signifying the ship's length measured in the direction of motion on her water line in metres.

v signifying the distance of her travel per second in metres.

(3) A solid in moving in a medium displaces permanently for a distance ($= d$), in inverse direction to its own motion, a volume of the medium equal to the product of its transverse average section ($= B / d$) and the distance of its travel, the transverse average section being as the solid's volume divided by its length, measured in the direction of its motion.

(4) A solid of non-uniform section transverse to the direction of its motion, when moving in a medium, displaces of the medium in inverse direction to its own motion permanently a quantity measured by its own transverse average section ($= B / d$) multiplied by the distance of its travel, and it also dislocates passingly and in a lateral direction another quantity of the medium, that is measured by the difference between the transverse major and average sections of the solid as one factor and the distance of its travel as the other factor, this additional quantity of the

medium being caused to passingly move or dislocate, but occupying the same position after the solid has passed, as it did previously thereto, and the quantity of the medium $=$ distance of travel $\times\ B/d$ is inversely moved permanently for the distance ($= d$) (from fore to aft).

(5) The resistance to the movement of all solids in a medium is measured by the permanent displacement in inverse direction to their own movement of a quantity of the medium, which is the product of the solid's own transverse average section ($= B/d$) in the length of the solid's travel.

$$\left(= \frac{B}{d} \,.\, v \text{ per second.}\right)$$

And the conclusions for the measurement of power, required to overcome the resistance thus defined, as drawn from these five theoretical assertions, are as follows:

It is the *quantity*

$$f\,v = \frac{B}{d} \cdot v$$

of the water for every second, which must *receive an impulse* to flow in a direction inverse to the ship's motion, and the impulse given to the water must be sufficient to cause its flow with the stated *velocity*. And this impulse is equivalent with the raising of the stated quantity

$$f \,.\, v = \left(\frac{B}{d} \times v\right)$$

of water to an elevation

$$= S = \frac{v^2}{2\,g} \left(= S\frac{g}{2} = \left(\frac{v}{2}\right)^2 \text{ when } \frac{g}{2} \text{ is the unit for measuring distance.}\right)$$

It is, therefore, also true, that

(6) The power required for propelling a ship at a stated velocity per second ($= v$) is as

$$P = f\,v\,S = \frac{B}{d} \cdot v \cdot \frac{v^2}{2\,g} = \frac{B\,v^3}{d\,2\,g} \text{ kilogramme metres.*}$$

f signifying transverse average section $= \frac{B}{d}$

S signifying total distance of fall by acceleration of gravity;

B signifying the ship's immersed volume or buoyancy. When the total value is expressed in ton-metres, then B is expressed in cubic metres, but when the total value is expressed as kilogramme metres, then B is expressed in the corresponding of $0{\cdot}1^3{}_{\mathrm{m}}$ = litres = kilogrammes;

d signifying the ship's length measured in the direction of her motion and on her water line;

v signifying the ship's velocity in metres per second;

g signifying twice the distance, which matter, when free to fall will pass in the direction towards the earth's centre within the first second of such free fall. This distance g, being as $g = 9{\cdot}78009 + 0{\cdot}05080 \sin^2 \varphi$ (φ = geographical latitude) showing, that travel of ships for equal speed and distance requires less power on northern than on southern geographical lateral travel.

When movement in another medium than water is under consideration, the factor for density of medium must become part of the equation, which then will read

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* A railroad train, say of sixty cars of equal weight, each twenty feet long, moves within one second a distance of 400 feet. When stopping again forty cars will be, where forty cars were before, virtually not moved at all, and twenty cars, that were at the rear end, are there no longer, but appear at the front end, though they be not the same cars.

With B as the total weight (in vacuo) of the train in metric tons, with d as the length of the train in metres, and with v as the distance of travel per second, $B\,.\,v/d$ represents the mass moved per second, and $B\,.\,v^3/(d\,.\,2\,.\,g)$ represents the power required to move the train horizontally, when running with lubricated cool axles.

$$R = \delta \cdot \frac{B}{d} \cdot v \times \frac{v^2}{2g}$$

Comparing this equation with the equations representing the same value as developed by Weisbach, Rankine and Unwin, and expressed by uniform symbols with the exception of a, for which all three authorities have an essentially different interpretation, we find their equation to read

$$R = \delta \cdot Ms \cdot a \times \frac{v^2}{2g}$$

In both equations due consideration is accorded to the general character of the total value as that of "momentum," viz: as the product of mass and movement. The factor conditional to movement, representing gravitation by $v^2/2g$, is in both equations the same.

The factor "mass" is measured by the three authorities by

$$\delta \cdot Ms \cdot a$$

for which I make the attempt to substitute

$$\delta \cdot \frac{B}{d} \cdot v$$

this latter value representing a volume and corresponding precise weight of the medium, in which the movement of the solid takes place, and conditioned on the form of the solid either conforming, as in ships, to the molecular division lines of the medium, or on adequate but simple addition to such volume of what of the medium joins the solid in relative movement by adapting the moving form to the natural and peremptory lines of molecular division of the medium.

The value δ for density in both is identical, and as water is under consideration, when δ is $= 1$, and on account of identity this value may be dropped out of consideration.

The parallel remaining values then are:

$$Ms \cdot a$$

and

$$\frac{B}{d} \cdot v$$

The essential difference between these parallel values consists in this:

The value

$$f \cdot v = \frac{B}{d} \cdot v$$

signifies the precise volume and corresponding weight of the medium, which passes any stable point in the line of the ship's travel in inverse direction to such travel within the time limit of one second, and therefore is a true expression for mass per second and in consequence allows for the total value of resistance a concrete expression in kilogramme metres.*

Let us investigate the meaning and significance of the older valuation of "mass."

It first then appears, that the three authorities quoted are not authority for the same valuation.

Weisbach's interpretation of a ($= \xi$) is:

> "A coëfficient (experimental, unknown) of form of obstacle."

Unwin signifies by a ($= K$):

> "The ratio of the plate (face of solid) to the opening (transverse section) of pipe (medium causing percussion), and

Rankine expresses by a ($= K$):

> "A coëfficient (unknown) of form."

And Nystrom has been satisfied with none of these three authoritative valuations, but substitutes the value:

> "a by the two values a and b for the mean angles of resistance *fore* and *aft*."

With none of the four authorities $Ms \cdot a$ signifies a well-defined volume and weight. The factor a renders the product $Ms \cdot a$ dependent on other values to be looked for outside of the equation itself. But with all four authorities the value $Ms \cdot a$ represents resistance to percussion, and with all four authorities *Ms* stands for "transverse major section," as the condition to measuring continuous resistance.

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* Compare the preceding footnote relating to railroad trains.

In conflict therewith I make "transverse average section" conditional to measurement of continuous resistance, and the value for "transverse average section" is not, as *Ms* is, relating to a single set of constructive lines, but it relates to *all solids* of whatever different constructive lines, and is conditioned on their immersed or submerged volumes (B) being the quotient in said volume by the solid's length (d), measured in the direction of its movement, as divisor.

It is by the method of measuring the length d, that my equation not only measures the resistance to the progress of ship, when she proceeds on her way normally, this is in the direction of her greatest length, but measures resistance to her movement also, when she is moving diagonally or even in the direction of her shortest dimension.

In none of the older equations except Nystrom's is there any connection made with distance of travel ($t\ v$) or distance per second (v).

My equation accounts directly and concretely for the influence of distance as conditional to measurement of resistance.

I may therefore justly claim, on condition of proof being rendered for the facts as they are expressed by my equation, that for an indefinite, incomplete and comparative valuation of resistance to motion in a medium, dependent on unknown experimental coëfficients, I have substituted a definite, in itself complete and independent value for movement of a stable volume in a liquid or fluid medium, a value expressed in precise equivalents of kinetic energy.

[*To be continued.*]

PROCEEDINGS

OF THE

CHEMICAL SECTION

OF THE

FRANKLIN INSTITUTE.

[*Stated meeting, held Tuesday, February 21, 1893.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, February 21, 1893.

Dr. D. K. Tuttle, Vice-President, in the chair.

A letter from Prof. Henry Trimble was read nominating Mr. Josiah C. Peacock, 3909 North Fifth Street, Philadelphia, for full membership in the Section. As a result of the action of the Committee on Admissions, Mr. Peacock was declared elected.

Dr. Wahl reported that at the special meeting called by the President to consider the adoption of resolutions of respect to the memory of our fellow-member, Dr. F. A. Genth, recently deceased, a committee was appointed to draw up these resolutions, which were published in a number of the leading daily newspapers of Philadelphia. On motion the Section voted that the Treasurer be authorized to pay the bills incurred by the committee in the publication of these resolutions which read as follows:

Resolved, That the members of the Chemical Section of the Franklin Institute have heard with deep regret of the death of their distinguished fellow-member, Dr. Frederick A. Genth, whose eminent services as an investigator have added lustre to American science.

Resolved, That a committee be appointed to prepare a suitable memoir of the deceased for publication in the proceedings of the Section.

Resolved, That as a mark of respect, the Section be requested to attend the funeral in a body.

A paper on "Artesian Wells" by Professor Carter, of the Central High School, was read by title and referred for publication.

Dr. E. H. Keiser, for Miss Mary Bidwell Breed, of Bryn Mawr College, read a paper on "Phenolphthalein and Methylorange." The article was interesting and was well received. Quite an animated discussion as to the relative merits of the two substances as indicators was called forth and was participated in by Mr. Rowland, Dr. Keiser, Mr. Pemberton, Mr. Haines, Dr. Keller and others.

The paper was referred for publication.

Mr. S. W. Young, of Swarthmore College, then made a report of the most important results obtained in the field of stereo-chemistry up to the present time. A number of the theories, offered to explain certain interesting cases of isomerism, were stated and illustrated by models showing the supposed special relations of the atoms contained in the compounds considered. The paper was attentively received and on motion the Section voted that it be published in the *Journal.*

Adjourned. WM. C. DAY, *Secretary.*

A NEW PROCESS FOR THE MANUFACTURE OF MANGANESE ON THE COMMERCIAL SCALE.

BY WM. H. GREENE AND WM. H. WAHL.

[*Read at the stated meeting of the Chemical Section, held January 17, 1893.*]

Within a few years manganese has assumed considerable importance as a constituent of several alloys, and the purest manganese of commerce as well as the richest ferro-manganese have been unsatisfactory for the preparation of these alloys by reason of the high proportion of carbon invariably present.

About two years ago we were induced to undertake the search of a process for the manufacture on a commercial scale of metallic manganese that would contain a minimum of detrimental impurities and be absolutely free from carbon. Before describing the process which we have elaborated, we will review briefly the history of the element.

About 1774, Scheele and Bergmann demonstrated that the metallic radical of manganese dioxide is different from iron, and John* isolated the new element by heating a mixture of manganese carbonate and oil, powdering the resulting mass, again mixing it with oil and strongly heating in a brasqued crucible.

St. Claire Deville† modified this process as follows: He reduced pure artificially prepared dioxide to red oxide; mixed this with sugar charcoal in insufficient quantity to reduce the entire quantity of oxide, and heated the mixture in a lime crucible to the highest temperature of a wind furnace.

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* *Gehlen's Jour. Chem. Phys.*, **3**, 452.

† *Ann. de Chimie et de Physique* [3], **46**, 182.

Brunner[*] heated manganese fluoride, or a mixture of manganese chloride and calcium fluoride, with sodium in clay crucibles.

Giles[†] prepared a manganese amalgam by the action of sodium amalgam on a concentrated solution of manganese chloride, and expelled the mercury by heating in a current of hydrogen, thereby obtaining pulverulent manganese.

Bunsen[‡] obtained deposits of metallic manganese by electrolyzing a concentrated solution of manganous chloride.

The first attempt to produce the metal in considerable quantity appears to have been made by Hugo Tamm[§] who in 1872 published the results of experiments made on certain modification of John's method. Native dioxide was reduced by heating with powdered charcoal and oil in the presence of silicious and fluorspar fluxes in graphite crucibles.

The problem presented to us was the reduction of a native oxide of manganese, for it is apparent that the expense of preparation of halogen compounds of the metal and their subsequent reduction would preclude the possibility of applying such a method to manufacturing on a commercial scale.

At the outset of our work it became evident that the first step in the process would be the purification of the ore from iron, which would inevitably be reduced in the reduction of the manganese and could not then be removed from the metal. Magnetic separation appeared to be the cheapest and most effective method; and we made exhaustive experiments in this direction, the ore being treated in all states of division and in all conditions of oxidation, between that of the natural ore and that in which the manganese was reduced to manganese monoxide and the iron to metallic iron. We were compelled to abandon the method entirely, because the iron and manganese are so intimately associated in the ore that no satisfactory separation can be accomplished by the magnet.

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[*] *Pogg. Annalen*, **101,** 264.

[†] *Philosoph. Mag.* [4], **24,** 328.

[‡] *Pogg. Annalen*, **91,** 619.

[§] *Chem. News*, 1872, 111.

We then tried various electro-chemical methods, the ore being made the anode of baths containing sodium chloride solution, ferrous sulphate, dilute sulphuric acid, etc. By such means a certain proportion of the iron may be removed, but the separation is slow, and is far from complete when the manganese oxides begin to be attacked.

Convinced that only a chemical method would answer the purpose, we found after a number of experiments that nearly all the iron can be removed from rich manganese ores by digesting the pulverized ore with about thirty per cent. sulphuric acid near the boiling point, while the manganese is practically unattacked. As an illustration of the effectiveness of the process, we may state that in a few hours the percentage of iron may thus be reduced from five or six to a few tenths, with a loss of not more than one per cent. of the manganese present. The copperas that may be obtained by treatment of the waste acid with scrap iron, will pay the cost of purification of the ore.

The reduction of the ore has been a perplexing problem. While it has never been denied that reduction by carbon in any form yields a metal containing a considerable proportion of the reducing agent, the literature of the subject indicated that this combined carbon might be removed by fusion of the metal under a layer of manganous carbonate or manganous oxide. Thus, Tamm* claims to have obtained, from a pyrolusite containing 79·5 per cent. Mn. and 6·5 per cent. F_2O_3, a metal containing

Mn.	96·90
Fe	1·05
C	0·95
Other elements	1·10

and by refining this with manganese carbonate to have raised the proportion of manganese to 99·91 per cent. Other investigators admit the presence of more carbon in the product, but still claim that it may be removed by treatment with manganese carbonate. Our experiments show that the reduction by carbon takes place readily, and only after frequently repeated experiments, in which the proportions of oxide and carbon and the character and proportions of flux employed were varied through wide ranges, did we come to the conclusion that it is impossible by this method to prepare a metal containing less than about six per cent. of carbon, and that it is equally impossible by fusion with an oxidizing agent to remove carbon thus combined with manganese. The results of experiments recently published by Guntz* explain clearly these phenomena. He finds that carbon monoxide is rapidly decomposed by manganese at a red heat, carbon and manganese monoxide being formed. It can then be readily understood why carbon free manganese cannot be made in the electrical furnaces nor in graphite crucibles.

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* *Chem. News*, 1872, 111.

From all these facts we have been led to infer that the reduction of manganous oxide by carbon yields not manganese, but a definite carbide having the composition Mn_3C. We propose investigating this point in the future.

It then became evident that the problem could only be solved by a reduction taking place in the entire absence of carbon. Tentative experiments having given no encouragement to hope that an electrolytic method depending on the decomposition of fused baths of manganese chloride or manganese fluorides mixed with other chlorides and fluorides could be devised, the only alternative became a purely chemical process, the details of which were worked out during the progress of the laboratory work. The importance of these details will become apparent as we describe the steps of our process.

The pulverized manganese ore purified from iron, or containing less than one per cent. iron, is exposed to the action of reducing gases at a temperature approximating redness. All the manganese is thus converted into greenish-grey manganese monoxide, which must be allowed to cool out of contact with air to prevent oxidation to red manganoso-manganic oxide.

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* *Comptes Rendus*, **114**, 115.

The monoxide is then mixed with about eighteen per cent. of its weight of granulated aluminum and a suitable flux and the mixture is heated to a temperature near the melting point of cast iron in magnesite crucibles. The flux may be silicious or a mixture of lime and fluorides, or lime alone. As soon as the temperature of reaction is attained the mass promptly fuses and must be poured from the crucible while at its maximum temperature. While the character of the flux has little influence on the reaction, it has important relation to the yield and quality of the metal obtained. A silicious flux naturally occasions the introduction into the manganese of a certain proportion of silicon. If the flux be too fusible a quantity of the aluminum may rise to the surface and escape the reaction. A mixture of lime and fluorspar has given us the best results in crucible operations.

Theoretically, one part of aluminum should yield three parts of manganese; the best results we have obtained on the small scale, producing several pounds of manganese at one operation have given us two and eight-tenths parts or ninety-three per cent. of the theoretical yield, and our average yield has been about eighty-seven per cent. With aluminum at its present price we therefore estimate that the absolute cost of producing carbon-free manganese containing, Mn ninety-six to ninety-seven per cent., Fe and Si each one to two per cent., by our process, will be within thirty-five cents a pound, this estimate including all expenses.

On the large scale we purpose conducting the operation on a magnesite lined hearth, reducing gases being in slight excess. By this means we believe that the manganese will be retained in the state of lowest oxide until the temperature of reaction is reached, and that the prompt fusion of the flux at this stage will protect the manganese formed from contamination by carbon from the flame.

We may mention in conclusion that having experienced considerable difficulty in obtaining and preparing magnesite crucibles, we adopted the expedient of lining plumbago crucibles with a stiff paste of calcined magnesite. When properly prepared, these linings do not crack on drying, and do not shrink from the plumbago walls. After thorough drying, the crucibles are ready for use, and we have found the linings very serviceable, not only for the preparation of manganese, but in other metallurgical work in which silicious or plumbago crucibles were from any cause objectionable.

SOME PRINCIPLES THAT MUST BE OBSERVED IN ORDER TO MAKE A GOOD CLOSED-CIRCUIT BATTERY, AND A NEW PORTABLE DRY CELL DESCRIBED IN WHICH THESE PRINCIPLES ARE APPLIED.

By E. F. NORTHRUP.

[*A paper read before the Electrical Section, Dec. 28, 1892; Jan. 24, 1893.*]

The different types of primary batteries now upon the market are very numerous. Those acquainted with the subject know that all are more or less defective and that few, if any, give the efficiency that the theory of galvanism would seem to promise. Much excellent and exhaustive work has been done in determining the laws of electrolytic action and the general principles of chemical electricity, but fewer persons with the requisite chemical and mechanical knowledge have devoted themselves to the actual construction of cells which shall be free from practical defects and closely realize the theoretical possibilities.

The following general considerations may help to indicate the necessary limits to improvements in batteries and the paths in which to make an advance.

Prof. F. B. Crocker has shown, in a paper published in vol. v of the *Proceedings of the American Institute of Electrical Engineers*, the necessary cost of electric energy obtained by chemical means, and has reached the conclusion that primary batteries can never approach the dynamo in respect to economy or efficiency. There are, however, numerous cases, such as bell work, telephone, telegraph, medical and testing work where the cost of electric energy is of a secondary consideration and where a thousand watts may be worth as many dollars.

If a cell is to give a constant current, or in short, be an efficient generator of electricity, there are certain cardinal principles which must be observed. Most of the literature upon batteries states how they *have been* made, not how they *should be* made, it being customary to describe the construction of special cells rather than the broad principles of application to all types. The following is an endeavor to briefly indicate these principles:

All substances may be divided into (1) non-conductors; (2) conductors which are not decomposed by the passage of an electric current; (3) electrolytes or conductors which are decomposed by the passage of a current. A circuit made up of substances of the second class can never maintain a current except by the application of a foreign force or source of electro-motive force. If it did, the result would be perpetual motion. This source of energy outside of the circuit may be in the form of heat that is applied to the junction of two dissimilar metals in the circuit, in which case there is thermo-electric current. If, now, a substance of the third class, an electrolyte, is introduced into a conducting circuit of the second class, and a current is made to pass through the entire circuit, the electrolyte is decomposed, according to a well-known law. But it is not necessarily true, on the other hand, that because the electrolyte of a circuit decomposes a current will flow. The energy of decomposition may take the form of heat at the seat of the chemical action and then there is no current. This would be the case if two similar pieces of zinc, which made up part of a conducting circuit, were dipped in a strong solution of hydrochloric acid. Rapid decomposition of the electrolyte would ensue, but no current would flow. The condition essential in order that the energy of decomposition may take the form of a galvanic current, is that the decomposition which results shall be due to a *stress* in the electrolyte brought about by an unequal attraction of the two electrodes for the different constituents, or ions, as they are called, of the electrolyte. In order that this unequal attraction may be exerted, the electrodes must be at, what is called, a different potential from each other. This difference of potential may be brought about by the aid of an external source of electro-motive force, such being the case with the differently charged electrodes of a voltameter. Or, the two electrodes may tend inherently to maintain themselves at unlike potentials. Looked at from a chemical point of view, this inherent difference of potential possessed by the electrodes is the same thing as their unlike attraction or chemical affinity for the negative atoms or ions. The reason why different elements thus possess different potentials, or what is very probably the same thing, unlike degrees of chemical affinity, is not understood, but it is the fundamental fact which renders galvanic action possible. In short, the true source of the electric energy in a galvanic cell is to be found in the *unequal* chemical affinity which the two electrodes have for the atoms or ions of the electrolyte. Zinc and copper, for example, both attract chlorine, but zinc much more than copper, and hence negatively charged chlorine atoms will move from copper to zinc in an electrolyte of HCl. In the case of a $Zn/H_2SO_4/PbO_2$ couple, zinc has an affinity for SO_4, and PbO_2 has no affinity for that, but possesses a strong attraction for H_2, hence as each element pulls towards itself unlike ions, there is a strong stress in the electrolyte which means a correspondingly high electro-motive force.

The energy of the decomposition, when this is due only to the difference of potential of the electrodes, which produces the stress in the electrolyte, determines the force with which the current is urged forward, and a formula has been given by Lord Kelvin with which the electro-motive force of any combination can be calculated. (See Prof. F. B. Crocker's article, mentioned above.) This formula, however, only holds good in the case of a reversible element, viz: a cell in which all the energy of decomposition takes an electrical form, so that a reversal of the current will, theoretically, restore the cell. But under the ordinary conditions, as given above, an electrolyte will not continue to decompose, and the current at once ceases. The reason for this is that the constituents into which it is decomposed, the ions, are deposited upon the surfaces of the two electrodes. These electrodes, if originally of a different potential from each other, are soon brought by this deposit of ions upon them to the same potential, for the ions themselves, being reckoned in the tension series, are always of opposite potential to the electrode upon which they are deposited. But if these ions, by any means chemical or mechanical, are removed as fast as they are deposited, electrical equilibrium cannot be established and the current will continue to flow.

This brings us to the three essential features of any galvanic arrangement which will furnish a continuous current: (1) A medium capable of decomposition, and which is called the electrolyte. (2) Two undecomposable conductors which make contact with this electrolyte and which are removed from each other more or less in potential, the farther the better. (3) Some source of energy, chemical or mechanical, which shall remove the ions as perfectly as possible and prevent electrical equilibrium from being established; in short, a depolarizer.

If the cell is to be efficient, each of these three parts must act efficiently. The electrodes must be removed from each other in potential as far as possible, the electrolyte must be easy to decompose, the depolarizer must be active, and all three parts must have good conductivity.

Theoretically, two depolarizers are required, one for the positive electrode to remove the negative ions, and one for the negative electrode to remove the positive ions. Practically, only one is required, for the positive electrode has such a strong affinity for the negative ions which form upon it that its own atoms unite with the negative ions, the electrode itself being thus consumed or burned, and this consumption is the continued source of energy at the positive electrode. But, unfortunately, a like action does not take place at the negative electrode, when such electrode is an element, for carbons and the metals capable of forming the negative electrode do not have a sufficiently strong chemical affinity for the positive ions to unite with them in a like manner. There is one exception to this in the case of arsenic, when it is used as the negative electrode. For the positive hydrogen atoms will unite with metallic arsenic to form As_2H_4, and as the negative atoms at the same time unite with the positive electrode, the current will continue to flow though the cell employs elementary substances for its electrodes and has no depolarizer in the ordinary sense of the word. A couple, as for example $Zn / H_2SO_4 / As$, employs very cheap materials, but it gives only about seven-tenths of a volt and many other objections prevent this combination from being of much practical use. The solid elements, such as sulphur or iodine, which will unite with the positive ions, are non-conductors, hence it becomes necessary to introduce into the circuit about a negative electrode of good conductivity a strongly negative element, which will unite with the positive ions and remove them as fast as formed.

Now, whatever form of battery may be adopted, there are certain general principles applicable to each of these three essential parts of a cell, viz: the electrodes, the electrolyte and the substance which serves for the negative depolarizer, which must be taken account of in order to make the apparatus efficient.

The Electrodes.—It is difficult to conceive a case in which it would be preferable to have a given amount of energy in a large, rather than in a small space, hence, as electrical energy is the product of current and electro-motive force, it becomes desirable that the cell should have as high an electro-motive force as is consistent with other considerations. When all the elements are excluded, which are more costly than silver and those which are non-conductors of electricity, we have only the following list to choose from :

Potassium,
Sodium,
Magnesium,
Zinc,
Cadmium,
Aluminum,
Tin,
Lead,
Iron,
Cobalt,
Copper,
Antimony,
Bismuth,
Mercury,
Nickel,
Platinum,
Arsenic,
Carbon.

The Positive Electrode.—The first three of these elements, together with their zinc alloys, cannot be used in electrolytes which contain any water, as they almost universally do, because their affinity for oxygen is stronger than that of hydrogen and consequently the water is decomposed with a consumption of the electrode and with evolution of hydrogen gas. Cadmium, and the metals which follow it, give a lower electro-motive force than zinc and are not cheap enough as yet to make them more economical than zinc. Iron has been used, but it has disadvantages besides its low electro-motive force, such as the formation upon its surface of an insoluble and non-conducting film which runs up the resistance of the cell. Thus zinc, considering its cleanliness, cheapness and high potential, appears to be the best metal to employ for the positive electrode. Amalgamating it diminishes local action and slightly raises its electro-motive force. It may be alloyed with advantage only where fine adjustments of electro-motive force are sought, as might be the case in cells designed for standards of electro-motive force.

The Negative Electrode.—Much greater opportunity is offered for improvements in the negative electrode, both in respect to material and form. Negative electrodes may be divided into (1) those which are depolarized by an element not chemically united with the electrode; (2) those in which the depolarizing element is chemically united with the electrode, and (3) those which depolarize themselves chemically, as in the single case of arsenic, or mechanically, as by the exposure of a large extent of surface.

If the first class is used, then the following considerations must determine its material; the lower its potential the better. But if the depolarizer that is used is reduced by the action of the current to a metal which is deposited upon the electrode, then the electrode must have exactly the same potential as the reduced metal. Otherwise wasteful local action may take place, for a couple will be formed between the reduced metal, which is at one potential, and the electrode, which is at another. For example, with copper oxide for a depolarizer, copper and not carbon should be used for the negative electrode.*

When, on the other hand, the depolarizer is an element, or a compound which is reduced to an inert material, such as PbO_2 reduced to PbO or Pb_2O_3, carbon makes by far the best electrode. It is cheap, nearly as negative as platinum, and, as we shall see later, can be made to serve the purpose of a porous cup as well as electrode.

The second class of negative electrodes, viz: those in which the depolarizing element is chemically united with the electrode, as is the case in the chloride of silver cell, is better discussed under depolarizers. The third class can at the best only be of service in open-circuit cells and will not be considered here.

The form given to the electrode is often quite as important as its material, especially when carbon is used. Most of the solid compounds employed as depolarizers have a high resistance, and all the elements which will serve the purpose are by themselves non-conductors (arsenic excepted), hence, if the carbon electrode is embedded in such a depolarizer and exposes but a small surface, the cell will have a high internal resistance and much of the electrical energy will be unavailable, as it will spend itself in heat within the cell. This is the way cells are often constructed, viz: with an electrode surrounded with a depolarizer of low conductivity. Liquid depolarizers, excluding the liquid element bromine, are not open to this objection, and hence the high efficiency of the Bunsen element, the gravity cell and others of that class. The best form to give the carbon electrode, for overcoming the internal resistance which results from using depolarizers of low conductivity, will be more clearly understood after a discussion of the depolarizing elements.

The Electrolyte.—The qualities, physical and chemical, which place a substance in the third class and make it an electrolyte, are so numerous that they can only be briefly mentioned here. Those interested are referred to "Meyer's Modern Theory of Chemistry," 1888 edition, page 532.

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* Since the above was written I have made experiments which show that salts of mercury and carbon can be used together without any appreciable local action taking place. E. F. N.

In general, no substance is an electrolyte which does not contain one or more of the six elements, S, O, Fl, Cl, Br and I. No substance will act as an electrolyte unless its particles are mobile and hence crystalline salts and solids in order to act as such must be either fused or dissolved in a liquid. Glass, for example, when fused becomes a very good electrolyte. Though pure water, alcohol and ether are non-conductors, the first becomes a very good one when mixed with certain substances, and the last two also become conductors when some salts are dissolved in them.

All electrolytes decrease in resistance with increase in temperature, and this makes one of the tests of the class in which to place a substance. Generally speaking, a dilute solution has a lower resistance than a concentrated one. Acid and alkali electrolytes give, as a rule, higher electro-motive forces than salts, but they are open to the objection of being liable to consume the positive electrode, which means that some of the energy stored up in the cell is given out in local heat instead of electricity. As a rule salts are better adapted to hermetically sealed cells, and acids or alkalies to open cells. If a salt is used, it should usually be a salt of the metal employed for the positive electrode with an acid radical the same as the active depolarizing element, for after the cell has been in action such a salt is always formed, and if other salts are present there is a liability that double salts may be produced, which will increase the resistance of the cell, or at least make complicated what might otherwise be simple. Thus in a zinc carbon couple, with bromine for a depolarizer, zinc bromide would be better to use than magnesium chloride. This is not, however, an inflexible rule to follow, for special cases may require special salts. The relations of the different excitants and their degrees of concentration to the electro-motive force obtainable with different combinations of electrodes has been fully worked out by investigators, and the results of the same are well presented in Tommasi's "Traité des Piles Électrique," which work, by the way, is one of the best records of what has already been done in the practical construction of galvanic batteries.

It may be observed here, that as water is almost always present in the electrolyte, its hydrogen is deposited upon the negative electrode and causes the polarization. This is *always* true where the excitant salt is an oxygen salt of an alkali or alkaline earth metal, and generally so with other salts. This is due to a secondary action which takes place. If, for example, a salt of a positive metal like sodium is employed, when the metal is separated from the acid radical it at once decomposes the water and frees its hydrogen, the metal itself forming a hydroxide with the remaining portion of the decomposed molecule of water, thus

$$Zn_x + 2\ NaCl + 2\ H_2O + C = Zn_{x-1} + ZnCl_2$$
$$+ 2\ NaOH + H_2 + C,$$

or

$$Zn_x + 2\ KOH + 2\ H_2O + C = Zn_{x-1} + Zn\ (OH)_2$$
$$+ 2\ KOH + H_2 + C.$$

In fused electrolytes, where no water is present, this action, of course, cannot take place.

A further discussion of electrolytes would be more interesting from a scientific than from a practical standpoint, for they have never given trouble in the actual construction of an efficient battery. The chief thing that has to be taken note of is that the excitant is not of a kind or concentration to dissolve any part of the cell and produce local action. This is the reason that KOH cannot be used with advantage in a silver chloride cell, though the electro-motive force is much greater than with NH_4Cl, which is usually employed.

The Depolarizer for the Negative Electrode.—As the negative electrode is polarized by the formation upon it of hydrogen, it can only be chemically depolarized by such substances as will unite with nascent hydrogen. Now, whatever compound is used, the depolarizing is actually done by one of these seven elements, As, S, O, Fl, Cl, Br or I, or one or more of these in combination. Theoretically, some other elements belonging to the group of non- or semi-metals will unite with nascent H, but their affinities for H are weak and practically could never with advantage be used. Arsenic and sulphur also have weak affinities, giving under the most advantageous circumstances less than a volt and generally less than half a volt. Fluorine is far too powerful to be used, either free or in combination. So, practically, a battery always makes use of O, Cl, Br or I for its negative depolarizer, though these may often act in a combined state as in the case of the acid radical SO_4. As the depolarizing is actually done by one of these four elements or two of them in union, it is obvious that the other element or elements with which they may be combined are so much inert material which play no part in the production of the current, and usually only act to clog up the cell, increase its internal resistance and add to the total bulk occupied by the materials. Hence, the theoretically perfect cell would employ electrodes at opposite ends of the potential scale, and have the negative electrode depolarized with the most negative free element. The parts would be so adjusted that all would be finally consumed at the same time, and the cell go to pieces like Dr. Holmes' "One Hoss Shay." There are certain difficulties connected with the use of free elements as depolarizers, which have led to the adoption of their compounds instead. In the first place, any element or compound which will give up an element capable of uniting actively with hydrogen, and hence serve the purpose of a depolarizer, will also attack the positive electrode of the cell. Therefore, the depolarizer must be kept separated from the positive metal. The difficulties of doing this are increased when the depolarizer is a liquid or gas. Oxygen and chlorine being gases, and both of them also but slightly soluble in water, are thus difficult to employ. Bromine and iodine in an unmixed or uncombined state have the disadvantage of being non-conductors and must be used in some special way if the current is to find free passage between the electrodes. The former, moreover, is an exceedingly penetrating liquid, which will diffuse with great rapidity through any porous partition which will permit the passage of the ions. Iodine, though much easier to handle, and though nearly insoluble in pure water, is soluble in iodides of the metals and has heretofore only been used for experimental purposes. But whether an element or a compound be used for the depolarizer, it must be kept separated from the positive electrode. (1) This may be done by making the depolarizer an insoluble compound which will not tend to diffuse through the electrolyte. (2) By using a heavy oily liquid in the bottom of a cell which has no tendency to mingle with water. (3) Imperfectly by using porous cups or the gravity principle.

It is obvious that only cases one and two are applicable to small sealed portable cells, for if the depolarizer has a tendency to diffuse, no porous partition or gelatinous paste which will permit the passage of the ions will permanently arrest the action of diffusion, and a small dry cell made with a depolarizer which has a tendency to mix with the electrolyte will surely and inevitably carry on a local action resulting, in time, in its destruction. To be sure, this process is a matter of *degree* and may be greatly delayed and possibly kept back long enough to make a cell constructed upon this principle that is not invaluable. I may say here, however, that I experimented with small cells having a soluble depolarizer, which I attempted to keep in place by means of porous partitions and gelatinous pastes and found it to be practically impossible to make one that would last, upon open circuit, above a few months.

In respect to efficiency, a liquid depolarizer is much better than a solid depolarizer, and a gas best of all, for with solid substances the exhausted particles cannot be replaced as in the case of liquids and gases. For this reason the compounds PbO_2, MnO_2 and others of similar qualities do not depolarize effectively, or if they do, at least cause a high resistance in the cell. There is an exception to this rule in the case of cells made on the principle of the silver chloride and copper oxide cells, in which the reduced metal is left in a spongy state which permits the hydrogen to be absorbed into its mass until it comes in contact with the still unreduced oxide or chloride.

Of the free elements bromine, while being one of the cheapest, is a very powerful depolarizer, giving with the combination Zn / $MgCl_2$ / Br / C, 1·9 volts. It is comparatively easy to handle, and when dissolved in CS_2 loses largely its fuming nature and if properly used does not lose its depolarizing properties. Some experiments made with this element showed that the carbon electrode could be made to serve the double purpose of electrode and porous cup. This was accomplished by taking a piece of an ordinary electric light carbon and boring a three-sixteenth inch hole down the centre for a distance of two inches. This hole was filled with grains of carbon, and free bromine was then poured into the hole. The hole was stopped with a carbon plug and connection made with a platinum wire. Such an electrode, ½ inch in diameter and 2 inches long, was placed in the centre of a five-ounce beaker containing a sheet of zinc for the positive electrode and with an excitant of KOH. This arrangement gave over two volts and three and one-fourth ampères as read upon a low resistance ampèremeter. Such a high efficiency was of short duration, as the bromine soon became exhausted, but the experiment goes to show that use may be made of non-conducting liquids for depolarizers when applied in this way. If porous cups could be dispensed with and the free elements O, Cl, Br or I in solution used in some such manner as the above, a very high efficiency might be attained.

I do not attempt to give details at this time about the construction of cells which make use of the free elements, but merely wish to point out the direction in which I believe increased efficiency in the production of galvanic electricity must be sought.

The difficulties in finding a suitable depolarizer for an hermetically sealed transportable cell are much greater than for an open battery which remains stationary. The sealed closed circuit cells now upon the market, which are good for anything, use a silver salt, which, under the most perfect conditions, will make a horse-power cost 119 times as much as it can be obtained for with free bromine, or five and one-half times as much as with free iodine. This observation is made, however, on the assumption that the silver used is not recovered. As above stated, the depolarizer must be a solid, or at least of an oily nature, so that it will not diffuse through the electrolyte. If the salt of any metal is used which is reduced by the action of the hydrogen to the metal a potential of not over one and one-half volts can possibly be obtained (unless the rarer metals, such as osmium are made use of), and the cells that give that potential have some serious defects. If, on the other hand, an oxide like PbO_2 is used, which is not reduced to the metal, a higher electro-motive force is possible, but the resistance of such a cell is quite sure to be high. Moreover, the list of insoluble depolarizers which will give an electro-motive force of over a volt is not long. Among the free elements, oxygen and chlorine, being gases, cannot be used. Bromine and iodine, however, may be, and it is these elements that are employed in the new cells to be described.

Non-essential Parts of Cells.—Besides the three essential features of every battery, viz: electrodes, electrolyte and depolarizer, there are certain other parts often required that deserve a few words.

The case for a cell is usually made of glass, but often zinc, copper or carbon are employed, and serve for one of the electrodes of the cell. If this arrangement is adopted and several cells are used together, they must be insulated from one another, so that economy in space is not necessarily gained. This plan is usually adopted to obtain surface and so reduce the resistance of the cell.

In all so-called dry cells the electrolyte is used in the form of a semi-liquid paste. As this paste is usually employed, it merely serves the purpose of holding the contents of the cell in a more or less rigid condition, by which means the battery is made more readily transportable than it would be if it contained a liquid free to move about. But the paste in a hermetically sealed cell can be made to serve a much more important function. Where the product of the union of the hydrogen with the depolarizing element is an acid, this acid must be neutralized, in order to prevent its action upon the zinc and the consequent formation of a gas. This is best accomplished by the use of a paste which consists of some basic material. All organic substances, like starch or the hydrate of silica, which are often used as pastes, are non-basic and will not serve the purpose of neutralizing an acid, and in a small cell are of little value. Any cell which uses as its depolarizer a salt with a haloid acid radical, should therefore make use of some such product as MgO or ZnO if gassing is to be prevented. The neutralizing action of the paste which takes place may be shown thus:

$$ZnO + 2\ HBr = H_2O + ZnBr_2$$

or

$$Mg\,(OH)_2 + 2\ HCl = MgCl_2 + 2H_2O.$$

The objection may be raised to this view of the function performed by a paste consisting of a basic salt, that the acids formed by the action of the cell are exactly neutralized by a corresponding amount of alkali supposed to be formed at the same time, and hence the basic salt in the paste is superfluous. If we examine the following equations, which are supposed to represent the normal action of a $Zn_1/NH_4Cl_1/AgCl$ cell, the above objection would appear to be valid, thus:

$$Zn_x + 2\ NH_4\,Cl + 2\ H_2O + 2\ AgCl =$$
$$Zn_{x-1} + ZnCl_2 + 2\ NH_4OH + 2\ HCl + Ag$$

and then

$$NH_4OH + HCl = NH_4Cl + H_2O$$

and so no acid remains to be neutralized. This normal action, however, does not in reality take place, especially when the cell is worked hard. It is probably very much more complicated and is a thing very difficult to investigate. Practical experiments were tried, using a basic paste on the assumption that acid is formed in the cell in excess of an alkali, and is the cause of the hydrogen gas which is certainly produced in considerable quantity and that this paste would thus prevent gassing by neutralizing the excess of acid. The assumption was evidently correct, as numerous trials made of such a paste was found to prevent the gassing not only in the silver chloride cell, but in several other types having depolarizers containing one or more members of the hydrogen group.

The same objection is open to a paste that applies to solid depolarizers, viz: they do not allow diffusion of exciting liquids to take place as freely as it would in a liquid electrolyte. This objection, however, is proved by experiment to be much less than would be supposed. The resistance, moreover, caused by the use of a paste, if properly made, is insignificant.

[*To be continued.*]

ANNUAL REPORT OF THE BOARD OF MANAGERS OF THE FRANKLIN INSTITUTE.

(For 1892.)

The Board of Managers of the Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts, respectfully presents the following report of the operations of the Institute for the year 1892:

MEMBERS.

Members at the close of 1891,	2,073	
Number of new members elected who have paid their dues,	98	
		2,171
Lost by death or resignation,	57	
Dropped for non-payment of dues,	81	
		138
Total membership at close of 1892		2,033

FINANCIAL STATEMENT.

Balance on hand January 1, 1892,		$349 67
Receipts:		
Contributions from members, annual,	$5,034 00	
Contributions from members, life,	350 00	
Certificates of stock, second class,	10 00	
Income from legacy of Geo. S. Pepper,	1,252 50	
Income from Bloomfield Moore fund,	672 39	
Income from memorial library fund,	60 00	
Interest on investments new building fund,	340 00	
Interest on B. H. Bartol fund,	60 00	
Interest on investment of Institute funds,	794 00	
Temporary loan,	4,350 00	
Cash from mortgage, belonging to B. H. Moore Fund,	10,000 00	
Cash from subscriptions to, and sales of, the *Journal*, fees for drawing school and other sources,	8,860 78	
		31,783 67
		$32,133 34

Payments:

Committee on library,	$1,088 06	
Committee on instruction,	2,255 08	
Curators,	2,017 55	
Salaries and wages,	4,618 00	
Insurances,	900 00	
Bloomfield Moore fund expenditures,	660 87	
Memorial library fund expenditures,	20 39	
Temporary loan,	2,350 00	
Interest on temporary loan,	83 34	
Investments, Bloomfield Moore fund,	10,000 00	
Other expenditures,	7,963 08	
		$31,956 37
Balance on hand December 31, 1892,		$176 97

LIBRARY.

The annual report of the Committee on Library exhibits the fact that the additions to the Institute's collection of books, pamphlets, etc., during the past year have been below the average of the previous three or four years, although a fair increase is shown. This falling off is due principally to the fact that the committee's appropriation for the year 1892, was curtailed by one-third, this restricting them materially in the matter of purchases.

The policy in respect of the use of the Library for consultation by the public that was instituted in 1888, has been pursued, and while it has been found at times to throw considerable extra work upon the limited force of employés, it is probably as satisfactory a plan as could be devised.

The details of the year's work in the Library appear in the committee's annual report, to which the Board refers.

THE JOURNAL.

The *Journal* has fully maintained its excellent reputation. The Committee on Publications has given to its conduct and management the same careful and intelligent consideration as in previous years, and have continued to keep it on a self-supporting basis.

With the approval of the Board, the committee has been authorized to make the experiment of sending the *Journal* to all members of the Institute, beginning with the January impression of the current year and without present increase of annual dues.

It is confidently anticipated by this step that the interest of the membership generally in the work of the Institute will be increased.

Further information respecting this important departure from long-time usage appears in the committee's report.

To insure that the Institute shall not be at any pecuniary loss in carrying this project into execution, the committee with the co-operation of a number of the members who are convinced of the wisdom of the measure in promoting the welfare of the Institute, has obtained subscriptions to a guaranty fund which it is believed will be adequate for the purpose until such time as the growth of the business of the *Journal* shall be sufficient to meet the increased cost of publishing its enlarged edition.

COMMITTEE ON SCIENCE AND THE ARTS.

The annual report of the Committee on Science and the Arts shows that the committee has fully maintained its activity. The great interest displayed by the members of this committee in conducting the frequently exacting and laborious duties incident to the investigation of inventions submitted to them by applicants for reports or by the Institute, is most praiseworthy, and the Board is satisfied that the interests of the Institute are well served by this committee. The annual report of the committee will exhibit the details of the work for the year.

LECTURES.

The arrangement of the lecture course for the season of 1892–93 has been made upon the same lines as those of the preceding few years. The Committee on Instruction, with the co-operation of the professors, succeeded in maintaining the high character of these lectures by securing the services of many men of eminence, and the publication of many of these lectures in the *Journal* has added greatly to its interest, and at the same time to the reputation of the Institute.

DRAWING SCHOOL.

The number of pupils in the Drawing School is shown by the accompanying statement:

At spring term of 1892, ...	199
At the winter term of 1892, ...	200
	399

being a decrease of 106 as compared with attendance of 1891.

The chief reason for this falling off in attendance is doubtless to be sought in the growth of facilities for this species of instruction in other local institutions.

SECTIONS.

The continued activity of the Chemical and Electrical Sections is gratifying. The Electrical Section especially shows a highly gratifying growth both in membership and in the number and interest of its papers and discussions.

The influence of these two bodies in encouraging and promoting original research is of the highest importance, and the Board refers to their work with special satisfaction. The annual reports of the Sections will exhibit the details of their operation during the year.

STATE WEATHER SERVICE.

The Committee on Meteorology with the coöperation of the Assistant assigned to the work by the Weather Bureau at Washington, has succeeded in maintaining substantially unimpaired the organization of the State Weather Service, thanks to the interest and zeal manifested in the work by the voluntary observers in the various counties of the State.

Thus, the continuous record of the meteorology of the State has been kept unimpaired.

Through the courtesy of the Honorable Secretary of Internal Affairs, also, the committee has succeeded in having the monthly summaries of the reports of the observers and certain important special reports printed and has been enabled to include these in the *Journal* without cost to the Institute.

It will be of interest to state that the World's Fair Commissioners of the State were sufficiently impressed with the value of the service to grant an appropriation of $1,700 to provide for an adequate exhibit of its work, which will embrace illustrations of its methods, instruments, charts and other publications.

It is hoped that at the present session of the Legislature, the grant of an appropriation adequate to continue the work on a scale commensurate with its importance will be made. It is certainly earnestly to be hoped that this service, so importantly related to the commercial and agricultural interests of the State and so excellently organized for useful work, will be maintained unimpaired.

GENERAL REMARKS.

It is much to be regretted that a better exhibit cannot be made as to the financial condition of the Institute. The receipts for membership are even less than those for last year, which had decreased from those of the year previous. It is hoped, however, that the radical departure which has recently been made in furnishing the *Journal* to members, free of cost, thereby giving them not only a valuable return as an additional privilege for membership, but also keeping them thoroughly alive to the doings of the Institute, will tend to very much increase the number of members, both resident and non-resident.

For the latter class this privilege is especially valuable, as it gives a large return for a small fee, and furnishes a substantial inducement for such membership, notwithstanding the deprivation of the local use of the Institute building.

So much has been said in previous reports as to the extreme desirability of a fire-proof building with increased accommodations, that little can be added, except to keep the subject before the Institute and its friends.

It is hoped that some feasible way may be opened towards the accomplishment of what we know must be in the hearts of all who cherish and appreciate the Franklin Institute and its work.

By order of the Board.

JOSEPH M. WILSON, *President.*

ANNUAL REPORT OF THE COMMITTEE ON LIBRARY.

(For the year 1892.)

To the President and Members of the Institute:

GENTLEMEN:—The Committee on Library makes the following report, embodying the important facts concerning the operations of the library during the year 1892.

During the year, the following additions were made to the Library:

Bound volumes,	1,242	
Unbound volumes,	563	
Pamphlets,	1,174	
Miscellaneous publications,	528	
Total additions,		3,507
Being a decrease from the previous year of,		1,055
Total number of volumes in library, December 31, 1891,	37,183	
Additions bound and unbound volumes, during 1892,	1,805	
Total number of volumes at close of 1892, in library,		38,988

Pamphlets.—

Total number in library December 31, 1891,	22,183	
Additions during 1892,	1,174	
Total number at close of 1892,		24,357

The library also contained at the close of 1892, miscellaneous publications as follows:

Maps and charts,	2,476	
Drawings, designs, etc.,	604	
Photographs and lithographs,	1,150	
Newspaper clippings,	189	
Manuscripts,	21	
Total,		4,440

Duplicates.—The number of duplicates in the library at the close of 1892, numbered:

Bound and unbound volumes,	1,576
Pamphlets,	4,078
Periodicals (numbers),	3,051

Moore Fund.—During the year 1892, 190 volumes and eight unbound volumes were purchased from the income of the Moore Fund, and six volumes were bound.

Gifts.—The Library received by gift:

Bound and unbound volumes, ...	1,285
Pamphlets, ...	1,137
Miscellaneous publications, ...	626

Exchanges.—The number of journals and societies on the exchange list at the close of 1892 was 405.

Public Use of the Library.—During the year 1892, the Library was used by 783 non-members, who consulted 2,457 volumes of patents and 997 volumes and pamphlets from other departments of the library.

Use of the Library by Members.—The Library records show that 2,149 volumes were withdrawn for home use by 257 members. The number of volumes consulted in the library, not withdrawn for use, considerably exceeded this number.

A comparison of these figures with the records of previous years show that the additions to the library and the use of the library by members and others are about up to the average. The decrease in the number of additions, as compared with the year 1891, is due chiefly to the fact that the appropriation at the committee's disposal was less by the sum of $500 than that available for the preceding year.

Respectfully submitted,
W. P. TATHAM,
Chairman of Committee on Library.

ANNUAL REPORT OF THE CHEMICAL SECTION OF THE FRANKLIN INSTITUTE.

(For the Year 1892.)

JANUARY 1, 1893.

Mr. Joseph M. Wilson, President of the Franklin Institute:

SIR:—I have the honor to submit the following report of the proceedings of the Chemical Section for the year 1892:

Although no great advances over the results of the past few years have been made, the Section is in its usual prosperous condition, and as shown by the demand for the printed copies of its proceedings in other cities, as well as in Philadelphia, its work appears to be appreciated.

The officers for the past year have been as follows:

President, ...	DR. WM. H. WAHL.
Vice-Presidents, ...	DR. E. F. SMITH, DR. WM. H. GREENE.
Secretary, ...	DR. WM. C. DAY.
Treasurer, ...	DR. H. W. JAYNE.
Conservator, ...	DR. WM. H. WAHL.

Stated meetings have been held as required by the by-laws, on the third Tuesday of each month, excepting July and August.

Membership.—The number of members on the treasurer's books at the beginning of the year was seventy-nine; since that time three new members have been elected, four have resigned, one has died and one was dropped for non-payment of dues, making the present membership seventy-seven.

Finances.—The recently submitted report of the treasurer shows cash on hand at the beginning of the year $131.85, received during the year, $136; expenditures amounted to $193.79, thus leaving on hand a balance of $74.16.

The following is a list of the papers which have been read before the Section at its ten regular meetings.

"Analysis of Eggio," by Mr. Charles S. Boyer.

"A New Form of Gas-measuring Apparatus," by Mr. H. Pemberton, Jr.

"A Rapid Method for the Determination of Carbonic Acid Gas," by Mr. H. Pemberton, Jr.

"The Electrolytic Deposition of Aluminum," by Dr. Wm. H. Wahl.

"The Composition of the Explosive Copper and Silver Compounds of Acetylene," by Dr. H. Keiser.

"Notes on Iron in Bone-black," by Dr. Bruno Terne.

"Derivatives of Lapachic Acid," by Dr. S. C. Hooker.

"Chestnut Bark Tannin," by Prof. Henry Trimble.

"The Influence of Bottles upon Wines," by Mr. Charles E. Ronaldson.

"An Improved Method of Determining Small Percentages of Gold and Silver in Base Metal," by Mr. M. Cabell Whitehead.

"Armor-plate Tests at Indian Head Proving Ground," by Mr. F. Lynwood Garrison.

"On the Composition of the Liquid Ammonia of the Trade and How to Manufacture Liquid Ammonia of 99·995 Per Cent.," by Dr. Hans von Strombeck.

"Account of the Meeting of the Association of Agricultural Chemists at Washington," by Dr. Bruno Terne.

"The Washing of a Southern Coal: Comparison of Laboratory Results with those of Actual Washing Test," by Mr. Geo. W. Whyte.

"A Lilac Color from Extract of Chestnut," by Mr. T. C. Palmer.

"Deposits of Native Soda near Laramie, Wyoming," by Mr. H. Pemberton, Jr., and Mr. Geo. P. Tucker.

"Observations on Ferro-tungsten," by Dr. Wm. H. Wahl.

"Dibrom β-lapachone: its Preparation and Properties," by Dr. S. C. Hooker and Mr. A. D. Gray.

Approved at the stated meeting of the Section, December 17, 1892.

Respectfully submitted,

Wm. C. Day, *Secretary.*

REPORT OF THE ELECTRICAL SECTION OF THE FRANKLIN INSTITUTE FOR THE YEAR 1892.

To the President and Members of the Franklin Institute:

The Secretary of the Electrical Section begs leave to present the following report of the Section's proceedings for 1892.

Officers.—The business of the Section has been carefully and successfully conducted by the following officers:

President, ...	PROF. EDWIN J. HOUSTON.
Vice-Presidents, ...	MR. C. W. PIKE, MR. CARL HERING.
Secretary and Treasurer, ...	PROF. L. F. RONDINELLA.
Conservator, ...	DR. WM. H. WAHL.

Membership.—The Section now numbers fifty-one active members and eighteen associates, or a total of sixty-nine members. This is a slight increase over that at last report, fourteen names having been added to, and thirteen dropped from the roll during the year.

Finance.—The following is a summary of the Treasurer's report:

Cash in hand, December 30, 1891, ...	$15 68
Received from initiation fees, dues, etc., ...	97 12
	$112 80
Paid for printing, clerical work, etc., ...	103 93
Balance on hand, January 1, 1893, ...	$8 87

Meetings.—One special and ten regular meetings have been held during the year, at which there has been an average attendance of twenty-six. At the regular meeting of May, the Section's by-laws were amended by changing the time for regular meetings from the first to the fourth Tuesday of each month, excepting July and August.

Papers.—The following is a list of the papers that have been presented at the meetings of the Section, those indicated by an (*) having been printed in full in the *Journal of the Franklin Institute*, and in vol. ii of the Section's *Proceedings:*

"Recording Volt- and Ammeters." By H. S. Hering.

* "Electro-Magnetic Machinery." By Wm. S. Aldrich.

* "An Early Conception of the Magnetic Field." By Edwin J. Houston.

"Notes on the Power Transmission Plant at Niagara." "The Frankfort Electrical Exhibition." "Burton's Process of Electric Forging." By Carl Hering.

* "On the Variable Action of Two-coil Solenoids." By Wm. S. Aldrich.

* "The Constant Shunt Method for the Measurement of Continuous Currents." By C. W. Pike.

* "Cerebral Radiation." By Edwin J. Houston.

"The Oerlikon Works' Proposal for the Niagara Transmission Plant." By Carl Hering.

*"Dynamo and Motor Calculations." By C. H. Bedell.

"Experiments with High Potential Alternating Currents." (*Letter.*) By Elihu Thomson.

*"On Polyphased Currents." By P. Winand.

*"Ampère-çentimetre: A Measure of Electro-magnetism." By Carl Hering.

"The Magnetic Influence of So-called Non-magnetic Substances." By E. G. Willyoung.

*"A Graphic Representation of the Magnetic Field." By Edwin J. Houston.

*"The Physiological Effects of Alternating Currents of High Frequency." By Edwin J. Houston.

*"Magnetic Disturbances on Weston Measuring Instruments." By C. W. Pike.

"A Home-made Thomson Reflecting Electrometer." By D. A. Partridge.

*"On Polyphased Currents." (Second part.) By P. Winand.

*"Additional Notes on the Graphic Representation of the Magnetic Field." By Edwin J. Houston.

"The Plant and Process for Aluminum Plating the Ornamental Iron Work for the City Hall." By Wm. H. Wahl.

*"Some Curiosities in Early Electro-therapeutics." By Edwin J. Houston.

*"A New Ballistic Galvanometer." By E. G. Willyoung.

*"On the Measurement of Energy in the Three-phase System." By P. Winand.

*"Some New Apparatus for the Most Exact Comparison and Adjustment of Resistance Standards and the Determination of Temperature Coëfficients." By E. G. Willyoung.

*"Errors in the Determination of Areas from Measured Diameters." By O. T. Louis.

*"Recent Improvements in the d'Arsonval Galvanometer." By Nelson H. Genung.

"Some Principles that must be Observed in the Construction of a Good Closed Circuit Battery, and some New Portable Dry Cells in which they are Applied." By Edwin F. Northrup.

In addition to this, many interesting queries from the *Question-Box* have been discussed, and views and experience on practical subjects have been exchanged.

Outlook.—The recent slight increase in the Section's dues will considerably improve its financial resources, and systematic efforts are now being arranged by which the new committees will probably be able to increase the number of new members and arrange more attractive programmes for the meetings of 1893. The outlook, therefore, at the end of this second year of the Section's existence is very encouraging.

Respectfully submitted,

L. F. RONDINELLA,

Secretary and Treasurer.

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, Feb. 15, 1893.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, February 15, 1893.

MR. JOS. M. WILSON, President, in the chair.

Present, 116 members and eighteen visitors.

Additions to membership since last report, seven.

The resignations from the Committee of Science and the Arts of Messrs. Philip H. Fowler, John Hall, Lewis M. Haupt and Theo. C. Search were reported.

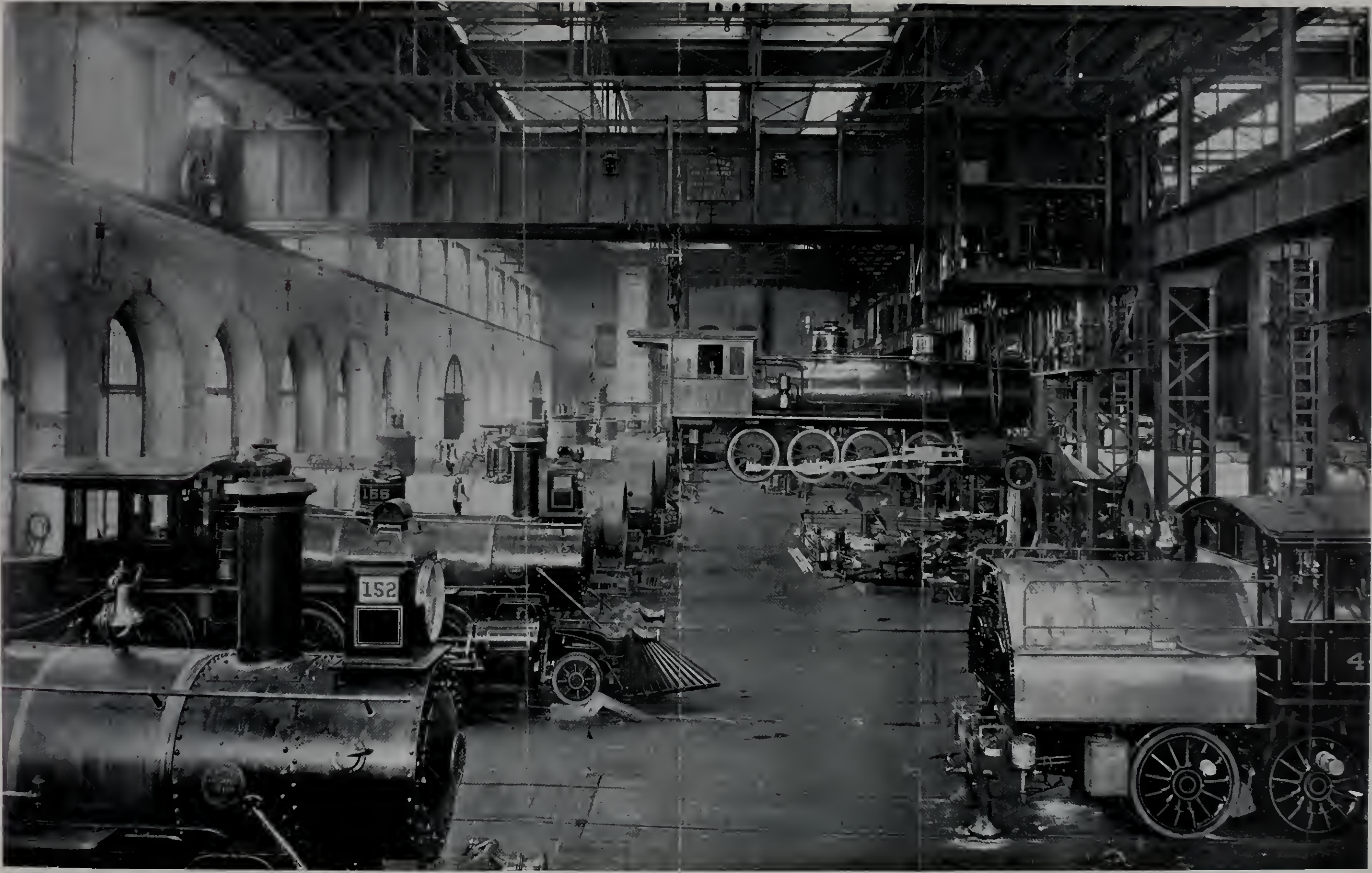
The vacancies were filled by the election of Mr. C. P. Schultz, in place ot Mr. Fowler; Mr. Walter Balliet, in place of Mr. Hall; Mr. E. G. Willyoung in place of Prof. Haupt, and Mr. A. P. Winand, in place of Mr. Search.

Mr. James M. Price read a paper descriptive of his improvements in rail-joints, illustrating the same by the exhibition of a series of specimen joints and with the aid of lantern slides.

Prof. Angelo Heilprin gave a popular account of experiences of Arctic travel, with special reference to the recent expedition for the relief of Lieut. Peary, of which he was the commander. His remarks were illustrated with a series of interesting views shown with the lantern.

The Secretary, in his monthly report, made reference to the alleged anticipation of Mr. Edison in the invention of the incandescent electric lamp, by Henry Goebel, and offered some comments on the evidence presented to sustain the claim of the latter to be the prior inventor.

Adjourned. WM. H. WAHL, *Secretary*.



100-TON HIGH-SPEED ELECTRIC TRAVELING CRANE INSTALLED IN THE NEW ERECTING SHOPS OF THE BALDWIN LOCOMOTIVE WORKS. MADE BY WM. SELLERS & CO., INCORPORATED, PHILADELPHIA, PA. [Span of bridge, 74 ft. 8 in.; length of run-way, 335 ft.; speeds (under absolute control) as follows: bridge travel, 100 and 200 ft. per minute; trolley travel, crosswise, 50 and 100 ft. per minute; hoisting and lowering, 5, 10, 20 and 40 ft. per minute.]

JOURNAL

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OF THE STATE OF PENNSYLVANIA.

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXXXV. APRIL, 1893. No. 4

THE Franklin Institute is not responsible for the statements and opinions advanced by contributors to the *Journal*.

THE MODERN TRAVELING CRANE.*

BY ALEXANDER E. OUTERBRIDGE, JR.

[*Read at the stated meeting of the Institute, held Wednesday, March 15, 1893.*]

Mr. H. R. HEYL, in the chair.

Mr. OUTERBRIDGE spoke as follows:

MR. CHAIRMAN AND GENTLEMEN:

Before proceeding to read the brief paper which I have prepared for this evening, I think, perhaps, that a few words by way of explanation of its motive may not be inappropriate.

It would seem almost superfluous to tell an audience, composed so largely of gentlemen who are engaged in mechanical pursuits and familiar with mechanical devices, that the problem which has confronted the modern manufacturer in his effort to produce larger machines of various kinds than heretofore—heavier locomotives, bigger bridges, more powerful war-ships and the thousands of other gigantic structures demanded in this era of mechanical progress—has been, not so much a question of the enlargement of factory buildings, or of increasing the melting capacity of furnaces, or of adding to the number of employés, but it has been mainly a question of obtaining adequate facilities for handling quickly and economically the enormously heavy materials composing such great structures, and I do not think it is an exaggeration to say that the limit of capacity of any establishment for such large work is determined by its facilities for handling its raw material with economy and despatch.

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* A paper read before the Franklin Institute, March 15, 1893, with an introductory address stenographically reported.

If you are given unlimited time and an unlimited amount of labor you can accomplish great results with exceedingly simple and crude appliances, but the more you try to economize time and labor in the performance of mechanical work, the more intelligence and skill you must crystallize into the forms of auxiliary machinery.

We all know that the simple dropping of water will, in time, wear away the hardest stone, but the little rock drill, which performs its work in a few moments, represents a high degree of mechanical efficiency.

The great pyramid at Gizeh, near Cairo, erected more than 4,000 years ago (or according to the generally accepted chronological records, more than six centuries before the time of Moses) stands to-day the largest structure of any kind ever erected by the hand of man. Composed of huge blocks of hewn stone, covering a space of more than thirteen acres at its base, equivalent to more than four squares of buildings in this city, it rises to a height of more than 450 feet or nearly twice the height of the tallest church spire in Philadelphia. The weight of this great mass has been computed at more than 5,000,000 tons.

Modern writers are fond of pointing to these facts as evidences that the ancients possessed mechanical appliances for handling heavy materials far surpassing those of the present time, but, until the two important factors of time and of labor are more clearly stated, I think we are justified in withholding our assent to such a broad inference. What did those autocratic rulers of Egypt care whether 100 or 1,000, or 100,000 slaves were employed for a year or a decade or a century in the construction of this great monument? They were building for all time, and had no thought of economy either of time or of labor in the construction.

The Greek historian Herodotus, who visited this pyramid about 400 years before the Christian era, tells us that it was regarded in his day as the most stupendous and most venerable monument of antiquity, and he further states that certain inscriptions on stone tablets recorded the fact that 100,000 men were engaged for thirty years in its construction. I have little doubt that if such a problem should be presented to our modern engineers it could be solved with the expenditure of a fraction of the time and labor represented in this great pyramid.

Coming now to a more modern illustration for the purpose of our comparison, I am reminded of an amusing story related of the late Matthias W. Baldwin, in the early days of his locomotive building in this city. The incident occurred, I believe, about the year 1840. One morning Mr. Baldwin received in his mail an order for twenty locomotives, coupled with the condition that they must be completed and ready for delivery within one year of the date of signing the contract. Mr. Baldwin declared that such a proviso with such a large order was preposterous, and that it would be impossible to complete the contract in the time specified. On looking over the illustrated history of the Baldwin Locomotive Works, I find that the total output for the year 1840 was nine engines, and it was not until thirty years had elapsed that the first 1,000 engines were completed.

The present capacity of the Baldwin Locomotive Works is about 1,000 engines a year. To what shall we attribute this enormous expansion? The enlargement of the buildings and the increased number of employés are important factors, but more men and larger buildings could have been obtained in former years, while the various modern appliances for expediting work were not then invented, by the aid of which the "impossibilities" of 1840 have become the ordinary realities of to-day.

For a final comparison, I would select an illustration in which you may all have a share. If I should ask any mechanic present to-night to close his eyes for a moment and form a mental picture of the appearance of the machine shop in which he acquired his technical education and to describe its most prominent features, he would probably say something similar to this:

"I see a long, low, dingy building with small windows and little semi-opaque panes of glass admitting feeble illumination; on the floor I see a miscellaneous assortment of machine tools—lathes, planers, boring mills, etc.—crowded together in some places, while elsewhere there are large vacant spaces. I see a number of masts or columns erected at intervals upon the floor, pivoted to foundation plates, and in many instances to the rafters. Attached to these masts are heavy swinging arms, strongly braced, carrying chains and hoisting tackle. A large casting is about to be transported from one end of the shop to the other, the chains are attached, the object is raised a few feet from the floor, it is swung round until the arm intersects the circle of the swing of the neighboring apparatus; it is now deposited upon a vacant space on the floor, again raised, again swung round and re-deposited, and so it is moved step by step until it reaches its final resting-place. Not only is a great deal of time lost in these operations, but valuable floor space also is permanently given up to the hoisting appliances and temporary resting-places for the castings."

Let us now, by the aid of the lantern, visit the new erecting shop of the Baldwin Locomotive Works, and see how this business is accomplished to-day. As we enter the shop, which is nearly a square long and half as broad, we are impressed with its unusual height, its light roof com. posed largely of glass, its immense windows admitting a flood of light and air. Upon the floor we see scores of locomotives in every stage of manufacture. We perceive that the entire floor space is occupied by the work in hand and we look in vain for the huge masts and arms, and, if we have not kept in close touch with recent progress in such matters, we may well wonder how these heavy materials are conveniently and expeditiously handled.

Presently we see an immense hook, not unlike the claw of some gigantic mythological bird, descend from above, grasp a cylinder or a boiler or possibly a completed locomotive of the largest size, and sail away with it as readily as though it were a toy. We turn inquiringly to our guide and ask, "What do you call this great mechanical power?"

The answer is contained in the title to my paper for the evening. It is the modern traveling crane.

The old-fashioned cumbersome jib-crane, slow of motion and limited in scope to the swing of its clumsy arm, so long a prominent eye-sore on the floor of every foundry and machine shop, is gradually disappearing, and is being superseded in progressive establishments by the *rapid-transit elevated railway traveling crane*, occupying no floor space and limited in range only by the walls of the building in which it operates. While this modern economical and expeditious method of handling heavy merchandise may still be regarded as a novelty, it has passed the experimental stage and the mechanism has already reached a degree of perfection which leaves little to be desired in respect of speed, safety, simplicity and accuracy of operation. This is the result of much study, costly experiment and practical experience.

The elevated railway traveling crane consists of four essential parts:

(1) The elevated tracks.

(2) The traveling bridge.

(3) The trolley car traversing the bridge and carrying the hoisting mechanism.

(4) The motor or driving mechanism.

The Tracks.—Two independent elevated tracks, with, in some types, parallel toothed racks bolted thereto, are supported by iron columns (or, in the case of a new building specially constructed, built in and supported from the walls).

These tracks run parallel to and close to the walls from one end of the building to the other. The bridge travels upon this runway propelled by positive gearing engaging with the racks, thus insuring perfect alignment under all circumstances.

The Traveling Bridge.—The bridge is constructed of two parallel plate girders extending from rail to rail, spanning in mid-air the breadth of the building. Four large double-flanged steel-tired wheels with steel axles running in bearings are bolted to projections on the girders, a skimming clearance only being permitted between the top of the rail and the bottom of the girders.

Between the girders heavy steel tracks are laid, bolted to their lower inner flanges, upon which a trolley car, carrying the hoisting mechanism, runs back and forth; thus, by the two motions, the longitudinal motion of the bridge and the cross-motion of the trolley every square foot of available space in the building can be covered.

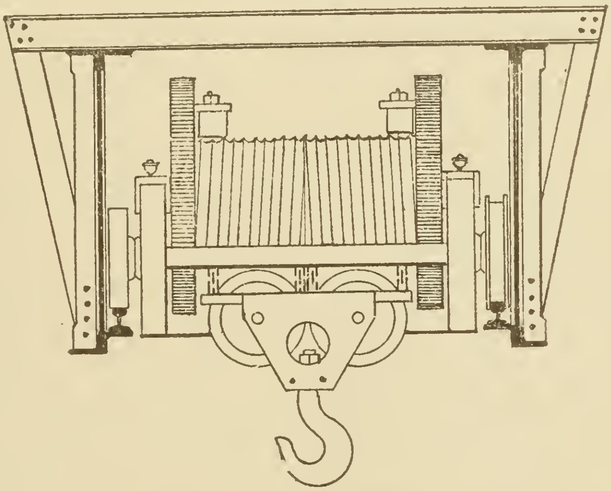
The girders forming the sides of the bridge are securely tied together by angle-iron braces and the bridge is still further stiffened against lateral strains by exterior girders, extending upwards and outwards at a sharp angle from the bottom flanges of the bridge members and bolted to struts or braces extending across the top of the bridge. By this method of construction great rigidity is secured, while the entire space within and beneath the bridge is left unobstructed for the working of the trolley car and machinery.

The Trolley Car and Hoisting Apparatus.—The car which travels on the bridge tracks is provided with a grooved drum and depending double chain wound thereon, carrying a forged swivel-hook mounted securely in a hoisting block on ball-bearings, the block being furnished with sheaves through which the chain runs. The friction on the swivel is so reduced by the ball-bearings that it was found in actual trial that a load of fifty tons suspended from the hook could easily be rotated by one man.

The winding of the double chain in the grooves of the drum is always towards the centre, this insures a perfectly vertical lift of the load, an advantage always, and a necessary feature in many instances.

The placing of the rails for the trolley on the top of the bridge, as is sometimes done, is open to serious objection on account of the tendency to produce unstable equilibrium of the bridge, or spreading of the girders, and disasters have occurred from the toppling over of the trolley when heavily loaded, due to these causes. It can readily be understood that these defects are eliminated by locating the point of support of the load on the lower inner flanges of the girders, instead of from a trolley on top of the bridge.

The racks meshing with pinions on both ends of the bridge prevent any tendency to mount the rail or to jam on the runway and permit of high speeds with safety, and, even if an accident should happen to the running gear of the bridge, such as the breaking of an axle, the bridge would merely settle down half an inch and then rest upon the rail.



Retaining clutches automatically hold the load securely from the moment it leaves the floor until it is re-deposited, the chain can never *run* down, but the load must always be *pushed* down by the operator moving a lever.

The operator's post is on a platform or cage supported at a convenient point under the bridge; by simple lever movements he applies the motive-power to drive the bridge along the rails and simultaneously to drive the trolley across the bridge, so that, during the two motions at right angles, the hook depending from the chain travels in the resultant diagonal direction until it is vertically over the object to be hoisted. A simple application of power revolves the drum lowering the chain, and when the object is attached a like delicate touch of the lever in the opposite direction causes the drum to revolve in the opposite direction, winding up the chain and lifting the object to the desired height. The bridge and the trolley are again started in their respective longitudinal and cross movements, the suspended object traveling in a straight line—the resultant of the two directions—from its starting point towards its destination, until vertically over the exact spot where it is to be deposited when it is a simple matter to lower and adjust it in place. The speed of all of these movements is under absolute control of the operator and the precision of adjustment where delicacy of movement is required, as in the setting of cores, closing of flasks, etc., is remarkable both for its perfection and for the ease with which the operation is performed. These movements may be, and frequently are, directed from below by the finger of the foreman.

The Motive-power.—Various motive-powers are applicable to operate a traveling crane; such as (1) an independent engine and boiler carried on the crane; (2) a square shaft, with tumbler bearings, bolted to the wall of the building; (3) an electric motor or motors. Each of these methods of driving the crane possesses individual peculiarities, and each offers particular advantages for special classes of work and convenient adaptation to peculiar environments.

The best evidence that these distinctions are understood and appreciated, is furnished by many large establishments, such as the Baldwin Locomotive Works, where all of these types, of recent construction, may be seen in the different departments, ranging from lilliputian cranes of five or ten tons capacity adapted to quickly shifting a cylinder, or other portion of an engine, from place to place in its progress from the condition of a rough casting in the foundry to a finished piece in the erecting shop, to the 100-ton electric giant which picks up a completed "Mogul" or "Decapod" engine of the largest size, carrying it swiftly over the heads of the workmen and depositing it gently on a railway siding near the exit.

While we have thus shown that there are various methods applicable to driving the traveling cranes and in daily use for that purpose, many persons regard the electric current as, *par excellence*, the modern method, and, in accordance with the demand thus created, large electric traveling cranes, having two trolleys on the bridge and five independent motors, have been constructed and are now in operation. A speed of travel on the run-way of 500 feet per minute is attained and a correspondingly quick traverse of the bridge by the trolley. These may be regarded as "lightning express" traveling cranes. The rate of travel or of hoisting is perfectly controllable from that of a snail's pace to the maximum speed, and the limit of speed is mainly a question of expenditure of power.

As a rule, a slow motion is required when the crane is hoisting and transporting heavy weights but the more rapidly the crane can travel from a locality in the building where its work is completed to another where its help is needed, and the more rapidly it can perform the preliminary operations of attaching chains to the object to be lifted (which tedious work may be said to occupy usually about nine-tenths of time during working hours) the more efficient the appliance becomes.

The method of operating a traveling crane by electricity forms the most novel type, and yet so rapid has been the evolution, that already several sub-types are included under this general head. When a single motor is carried on the cage the clutch system, similar to that used with the square shaft mechanism, is employed. In the three-motor or five-motor, or entirely electric crane, the clutches are discarded with the exception of one pair on the trolley.

In the electric system, one or more motors on the bridge or trolley are supplied with current from a dynamo by means of an overhead wire running the length of the building. By touching a few simple levers, or hand wheels, the wheels of the bridge are caused to revolve, the trolley car itself is caused to travel back and forth on its cross tracks, and the grooved drum carrying the chain and hook is caused to rotate, raising or lowering the hook, all of these motions being performed either at the same time or separately, in the same direction or in opposite directions, at the same speed or at different speeds, fast or slow, without confusion, by one man of ordinary intelligence. The operators are usually chosen from the ranks of unskilled labor, and are soon taught the simple movements. The levers are so arranged that the necessary as well as natural movements of the operator are in the direction he wishes the object to go, thus relieving him of embarrassment or uncertainty.

While this paper is designed to afford a general, or popular, yet accurate, description of the modern elevated railway traveling crane, and is sufficiently broad in its scope to cover the fundamental principles upon which all such cranes are constructed, we desire to point out in conclusion a few of the advantageous features which have been briefly alluded to *en passant*, characterizing the cranes made by William Sellers & Co., Incorporated, on which are lavished the results of indefatigable experiment, aided by extended experience in their shops, and in the manufacture and sale of cranes, covering a period of many years.

SPECIAL FEATURES OF THE SELLERS' TRAVELING CRANE.

Safety.—This is a factor of first importance in a machine designed to transport constantly enormously bulky and heavy materials over the heads of workmen, and has formed the key-note to the design of every part of the structure, for example:

(1) The plate girders forming the bridge not only have inherently an immense reserve factor of safety, but they are also tied together and strengthened by the angle-iron lattice girders on top, and by the external bracing extending from the bottom flanges to struts across the top in a manner entirely original and affording a degree of stiffness unattained heretofore. Furthermore, the maintenance of true alignment and prevention of twisting or jamming by means of the racks and gearing at each end of the bridge relieve

the girders of undue lateral strains and are peculiar to this crane.

(2) Double-flanged wheels with steel tires accurately turned to fit the head of the rail are substituted for cast-iron wheels usually employed for this purpose.

(3) Flat friction-clutches with broad bearing surfaces of positive action are substituted for conical clutches usually employed and of uncertain efficiency.

(4) Automatic support of the load at all times, requiring the use of power by the operator to release the tenacious grip of the clutches and push the suspended object down.

(5) The method of supporting the ends of the girders above the rails with a skimming clearance only, so that in case of accident to the running gear the bridge merely settles upon the rail.

(6) The placing of the trolley car between the girders, instead of on top of the bridge as is customary, contributes to the stability of the entire structure and is an evidence of the careful way in which correct principles have been elucidated and applied to all details. These are but samples of the numerous safety appliances.

Speed.—The ability to reach the load to be moved in the shortest possible time, whereby the preliminary operations of getting ready to lift are materially hastened, combined with the slow and steady pull, free from jar and susceptible of the most delicate adjustment, meets every desideratum.

Economy.—The location of all working parts upon or over the cage, within easy reach and sight, facilitating oiling, tightening of nuts, etc., by the attendant when not operating the levers; the ease with which parts may be removed for repairs, together with the ample proportions of each individual piece in its proper relation to the whole, all tend to minimize the cost of maintenance, while the economy of power in operation has been studied with equal care with the view to make this type of crane *the criterion* by which the merits of all other forms must be judged.

The traveling crane recently constructed at these works for the Columbian Exposition is an all-electric crane. The bridge has a span of 76 feet and the runway is will be 1,400 feet long; there are two trolleys on the bridge, with a lifting capacity of ten tons each.

The bridge is provided with an observation platform running its entire length, and upon this platform several hundred observers can be carried from end to end of the machinery building over the exhibits and far above the heads of pedestrians. The platform which carries the passengers does not interfere with the hoisting mechanism, so that this crane may be employed to hoist and transport goods and passengers at the same time, or alternately, if desired.

Such is a brief glance at the operation and capabilities of the traveling crane in general and of the Sellers' crane in particular. Its adaptability as to size, power and practical usefulness extends between wide limits. Cranes are in operation to-day, which will transport with equal ease a complete locomotive of the largest size or a delicate sand mould without disturbing a grain of the sand.

In the foundry and machine shop it makes the entire floor space available, and it is equally applicable in the stone yards, docks, and indeed wherever heavy materials require to be moved with celerity from place to place. A single operator with a single apparatus exceeds the capabilities of a dozen stationary cranes installed within reach of each other, effecting an enormous saving in time, labor and cost.

Thus, the modern traveling crane may fairly be regarded as one of the great inventions entitled to a high rank among the mechanical achievements of modern times.

FROM MINE TO FURNACE.

By JOHN BIRKINBINE.
President of the American Institute of Mining Engineers.

[*A lecture delivered before the Franklin Institute, November 14, 1892.*]

The lecturer was introduced by the Secretary of the Institute, and spoke as follows:

MEMBERS OF THE INSTITUTE, LADIES AND GENTLEMEN:

The mining or quarrying of iron ores, coal and limestone, from the earth; their preparation, handling, transportation, and the smelting of the ores into pig iron, offer the theme for what could be made an instructive story, increasing in interest as we take into consideration the earlier history of coal and ore mining and iron production, and as we note the improvement made in processes, and the advances in quantity and quality produced.

The story of iron production and manufacture is old. You have been told of Tubal Cain in the seventh generation from Adam, being "an instructor of every artificer in iron," and of the use of this metal in the pyramids of Egypt, and in the gates of the city of Babylon, of the ancient book of Job mentioning "bars of iron," "barbed irons," etc. This iron was probably made in the simplest possible manner, the ore being taken from the ground, and converted into wrought iron, with the aid of wood or charcoal in heaps in pits, or in crude furnaces. But we need not go far back to trace developments, for the past half century, or even the last twenty years, show more advancement in this specialty than all the preceding years since iron was first mentioned as a metal. I shall say little concerning iron as a metal, preferring to make this a connecting link between two lectures which I presented in this room, viz: "The Iron Ores of the United States" (delivered five years ago), and "The Development of the Pig Iron Manufacture in the

United States," delivered in February, 1891. The substance of neither of these will be repeated, except to call attention to subsequent developments, and to mention facts necessary to bring these two lectures into a connected story.

I shall not, therefore, consider the mining of ores other than those of iron, nor the production of any metal except the necessary incidental reference to pig iron.

To smelt iron ores a fuel and a flux are necessary, and in this country four fuels are employed, namely, anthracite coal, bituminous coal, coke made from bituminous coal, and charcoal. Coke is by far the most in demand for this purpose, and raw bituminous coal is used to but a limited extent, no record being now kept of the comparatively small portion of pig iron made with it exclusively. Including the output of furnaces using raw bituminous coal, alone, or mixed with coke, with those employing coke alone for this purpose, we find that of all the pig iron produced in the United States, 70·6 per cent. is smelted with coke and bituminous coal.

Coke is also liberally used with anthracite coal in varied proportions in the eastern part of the United States, 18·8 per cent. of the pig iron being made with these mixed fuels, and but 3·7 per cent. of our pig iron output being smelted with anthracite coal alone; the remainder, 6·9 per cent., is produced by the use of charcoal. At present the relative employment of the different fuels ranks in the following order:

Coke, sometimes mixed with raw bituminous coal.
Anthracite and coke mixed.
Charcoal.
Anthracite alone.
Raw bituminous coal.

Limestone is the universal flux used, although different conditions require stone of varying composition, from nearly pure carbonate of lime to a mixture of the carbonates of lime and magnesia, known as dolomite.

The iron ores fed to blast furnaces are also of varying composition; the convenience of these to furnaces, the yield of iron, the proportion of other ingredients which they carry, such as silica, lime, alumina, magnesia, phosphorus, sulphur, titanium, manganese, etc., and the expense of mining the ores influencing their use.

It is not within the province of this lecture to discuss the chemical composition of ores, but as the methods of producing different varieties, and the yield of these in iron will necessarily demand attention, a brief summary of the classification adopted is offered.

The iron ores produced in the United States may be divided into four general classes, without particular reference to their geological occurrence, but approaching within narrow limits the practice generally followed in the sale and purchase of iron ores.

(1) *Red Hematite*, all the anhydrous oxides of iron known by various names, such as red hematite, blue hematite, specular, micaceous, fossil, slate iron, martite, flax-seed ore, etc.

(2) *Brown Hematite*, including the varieties of hydrated sesquioxide of iron, variously known as limonite, gœthite, turgite, bog ore, pipe ore, pond ore, grape ore, and also some manganiferous iron ore, and most of the iron ores mined in the Rocky Mountain region for the smelting of argentiferous ores.

(3) *Magnetite*, those ores in which the iron is found chiefly as magnetic oxide: this class also includes some martite mined with the magnetite.

(4) *Carbonates*, those ores which contain a considerable amount of carbonic acid, such as spathic ore, siderite, black band, clay ironstone, etc.

COAL.

The universal use of coal makes the quantity employed for producing pig iron, though aggregating millions of tons, represent but a small percentage of the total output, hence a few facts only need be given of the production, preparation, handling, or utilization of coal. A review of the methods employed in various parts of the country would make a lecture of itself.

Great Britain and the United States are the two principal coal-producing countries in the world, followed by Germany, France, Austria, Belgium, Russia, Australasia, Canada, Japan, India and Spain, in the order named; these being the only countries which up to date have records of a yearly output of over 1,000,000 tons each.

The United States, occupying second position, produced in the year 1891, 150,500,000 tons of coal, or thirty per cent. of the total coal production of the world, variously estimated as from 500,000,000 to 550,000,000 tons in 1891.

In 1891, Great Britain produced 185,500,000 tons or 30,000,000 tons more than the United States. If, however, a retrospective view of the increase in the coal production in these two countries be taken, it will show that Great Britain's output since 1880 has augmented 38,500,000 tons, while that of the United States in the same period, shows an increase of 87,000,000 tons, and if this rate be maintained, it is probable that in the near future, the output of the United States will surpass that of Great Britain.

Of the other countries, Germany produced in 1891 94,000,000 tons (of which, approximately, one-fifth was lignite); France and Austria 26,000,000 each—two-thirds of Austria's product being lignite; and Belgium 20,000,000 tons. None of the other countries have yet reached a yearly output of 10,000,000 tons.

In coal mining, Pennsylvania occupies first place among the thirty-one States and Territories (including Alaska), which produce this fuel. According to the Census of 1889, it contributed fifty-eight per cent. of the nation's coal output, and more than one-half of what was credited to this State came from the anthracite coal fields of Eastern Pennsylvania.

As coal is used for so many other purposes, the consumption of this fuel in the production of pig iron can be only approximated. An estimate carefully prepared places the consumption in our blast furnaces in 1891 at 2,000,000 tons of anthracite coal, 12,000,000 tons of bituminous coal, principally converted into coke, and 66,000,000 bushels of charcoal.

It should be borne in mind that when referring later to iron ores, the amounts mentioned are of prepared ore ready for shipment, for the actual exploitation of the various mines demands a removal of quantities much in excess of those given. The brown hematites, as a rule, are washed to remove clay and foreign matter, and to enrich the ore, and often the amount of such foreign matter removed is four or more times as great as that retained. The carbonate ores must be roasted to remove their carbonic acid, and the roasted ores represent only about half the weight of the raw ores. Roasting is also applied to sulphurous ores, and hand sorting is employed liberally in the Lake Superior region. In addition to this the separation of comminuted ore, either by jigs or by magnetism, produces a ton of concentrated ore from one and one-half to five tons of crude material. It is therefore probable that for the production of over 14,500,000 tons of merchantable ore in 1891, fully 25,000,000 tons of material were removed from the ground.

The quantity of limestone used as a flux for blast furnaces in 1890, as reported to the United States Geological Survey, was approximately 5,500,000 tons, and in 1891 the amount thus used would be about 5,000,000 tons. We therefore have in round numbers 35,500,000 tons of raw material, mined or quarried, and prepared for market, to produce 8,250,000 tons of pig iron, nearly all of which has to be carried a considerable distance to points of consumption. If we allow for unmerchantable material mined and handled, it is probable that we would reach a total exceeding 50,000,000 gross tons annually. No attempt will be made to discuss the amount of labor required to produce, prepare, handle and transport this raw material. A statement of the quantity required is sufficient for present purposes, but some of the features connected with the handling and transportation of these materials will be offered.

IRON ORES.

The United States is at present the largest iron ore producing country in the world, her 1891 output of 14,500,000 gross tons being 1,750,000 tons more than her nearest rival, Great Britain, supplied in that year. Great Britain has in a former year, 1880, produced 18,000,000 tons, while the largest output of the United States was in 1890, when

16,000,000 tons were produced. Great Britain has, however, showed a great falling off in the output of her domestic iron ore mines, while her imports of foreign ores have been growing larger.

Of the other large iron ore producing countries, Germany contributed in 1891 over 10,500,000 tons, Spain approximated 5,000,000 tons, France 3,500,000 tons, Austria and Hungary over 2,000,000 tons, Russia 1,750,000 tons, and Sweden not quite 1,000,000 tons. Iron ores are also largely mined in Algeria, Italy (principally in the island of Elba), Greece, Cuba, China, and in smaller amounts in various other foreign countries.

Great Britain and the United States combined produce fully one-half of the iron ore mined in the world.

In the year 1887, when the lecture on iron ore was presented, this country was estimated as producing nearly 12,000,000 tons of iron ore; in 1890, the output of our domestic mines, as above stated, was over 16,000,000 tons; and although there was a marked decline in iron production and allied industries last year, the mining of over 14,500,000 tons of iron ore in 1891 shows an increase in five years of over twenty per cent.

There are no authentic records of the output of the different kinds of iron ores in the various States in 1887, or, in fact, for any years except 1880, 1889, 1890 and 1891, the first two being Census figures, while the last two were prepared for the division of mineral statistics and technology of the United States Geological Survey.

[The lecturer here exhibited a diagram, showing the amounts of the different kinds of iron ore produced in the various States in the four years above-mentioned. Only those States which mined over 100,000 tons of iron ore were shown, the smaller producers being grouped together under the head of "other States." Solid cross-section lines indicated red hematite ores; dotted cross-section lines, brown hematite ores; black blocks, magnetite, and dotted blocks, carbonate ores. The States were placed in the order of their precedence as total producers in the different years, *i. e.*, the State holding first rank was placed at the bottom of the column, and the second immediately above it, etc. The same scale was used in each of the columns, and the same tonnage in one year occupied equal spaces in any of the other years.]

The diagram shows a decided advance in the use of hematites, a slight decline in the proportionate amount of magnetites, and a very great falling off in the quantity of carbonates used in the decade.

In the year 1880, thirty-one and one-half per cent. of the total iron ore product of the country was red hematite; in 1889, it had risen to sixty-two and one-third; in 1890, to sixty-five and two-thirds per cent., falling off slightly in 1891, when the percentage of the total was but sixty-four.

The brown hematites constituted twenty-seven per cent. of the total iron ore mined in the United States in 1880, the proportion declining in 1889 to seventeen and one-third per cent., and in 1890 to only sixteen per cent., but advancing in 1891 to nineteen per cent. of the total

Thirty per cent. of the country's iron ore output in 1880 was of the magnetite variety; but in 1889, less than seventeen and one-third per cent.; in 1890, sixteen per cent., and in 1891, less than sixteen per cent. of the total was of this character of iron ore.

The percentages of carbonate ore used show a constant decline from eleven and one-half per cent. in 1880 to three per cent. in 1889, two and one-third per cent. in 1890, and one and one-third per cent. of the total product for the country in 1891.

While the above indicates a decline in the proportion of all the ores used except red hematite, a comparison of the outputs for 1880 and 1891 shows a material decrease in quantity in carbonates only; the magnetites and hematites having an augmented production.

The amounts of the different kinds of iron ore produced in 1891 were as follows: 9,327,398 tons of red hematite, 2,757,564 gross tons of brown hematite, 2,317,108 gross tons of magnetite, and 189,108 tons of carbonate ore, making a total iron ore product for the year of 14,591,178 gross tons. Of this total, Michigan contributed over 6,000,000 tons;

Alabama nearly 2,000,000; Pennsylvania over 1,250,000; New York, 1,000,000, and Minnesota nearly 1,000,000 tons; the total of these five States aggregating nearly 11,500,000 tons, or nearly seventy-eight per cent. of the country's output of domestic ores for 1891. This total will exceed 11,500,000 tons by adding scattered operations from which no returns were received. In addition to the American ores mined, nearly 1,000,000 tons of foreign iron ores were imported into the country. There was also considerable amounts of mill cinder, blue billy, franklinite slag, etc., used; but in tracing the ore from mine to furnace, these may be considered as being offset by the amount of iron ore which is used as fix in puddling and heating furnaces, as flux in silver smelting, and in the manufacture of paint, etc.

The relative rank of States as producers in the various years offers interesting suggestions as to the changes in their percentages of the iron ore output, and in the table below is given the total output of iron ores in 1880, 1889, 1890 and 1891, with the percentages of this total which each State produced:

	1880 *Per Cent.*	*1889* *Per Cent.*	*1890* *Per Cent.*	*1891* *Per Cent.*
Pennsylvania,	27·41	10·75	8·50	8·72
New Jersey,	9·50	2·86	3·09	3·60
New York,	15·83	8·59	7·82	6·97
Michigan,	23·04	40·34	44·54	41·99
Wisconsin.	0·52	5·77	5·92	4·04
Minnesota,	—	5·95	5·56	6·48
Alabama,	2·40	10·82	11·83	13·62
Virginia,	2·29	3·43	3·39	4·52
Tennessee,	1·31	3·26	2·90	3·73
Georgia,	1·15	1·71	1·52	1·72
Missouri,	4·84	1·83	1·13	0·73
Colorado,	—	0·75	0·71	0·76
Total output in gross tons,	7,120,362	14,518,041	16,036,043	14,591,178

All of the iron ore obtained from Minnesota in 1891, over seven-eighths of that from Michigan, nine-tenths of that from Wisconsin, three-fourths of that from Alabama and Tennessee, and nearly all of that from Missouri, was of the red hematite variety. Virginia is the largest producer of brown hematites (nearly all of its product being of that character of ore), followed in order by Alabama, Michigan, Pennsylvania, Georgia and Tennessee, as important contributors, and this is the only class of ore mined in the New England States, Texas, Oregon and some other States. Three-fourths of the total output of New York, over one-half the Pennsylvania product, and practically all of that obtained from New Jersey was magnetite, these three States producing seven-eighths of the total of this character of ore mined. Michigan follows New Jersey, then follow New Mexico and North Carolina as producers of magnetite. The State of Ohio was the only large producer of carbonate ore in 1891, although smaller amounts were obtained in New York, Pennsylvania, Kentucky and Maryland.

The product according to States does not properly represent the development of the iron ore industry, as well as that of certain prominent districts, and a diagram is presented to show the authentic record of such of the more prominent districts as could be obtained for twenty years past, or less. The rapid advance of the Lake Superior districts illustrates the growing favor of the blast furnace managers to the use of the rich red hematite ores. The combined lake and all rail shipments of the four districts will, in 1892, slightly exceed those of 1890. In this representation the importations of foreign ores (ninety-five per cent. of which were received at the ports of Philadelphia and Baltimore) were inserted for the purpose of comparison.

Even the product by districts does not truly show the remarkable extent which the development has reached in certain localities for nine mines in the Marquette Range, three in the Menominee, four in the Gogebic Range, and two in the Vermilion Range, have since their opening contributed from 1,000,000 to 6,000,000 tons each. The mines at Port Henry, N. Y., have yielded to date about 10,500,000 tons of iron ore, but no single deposit has equalled the record of the Cornwall ore hills in Pennsylvania, exceeding 12,000,000 tons, which have been obtained from this deposit, which has for a number of years averaged a greater output per annum than any other single mining enterprise, reaching its maximum of 769,000 tons in 1889. On three occasions, however, this maximum has been exceeded by the annual output of one of the Lake Superior mining companies.*

In the year 1891 there were but four mining enterprises in the country, the product of which exceeded 500,000 tons, although an equal number closely approximated this output. Two of these four great producers were located in Michigan, one in Minnesota and one in Pennsylvania. In addition there were in the Marquette Range three, in the Gogebic Range two, in the Menominee Range one, in Minnesota one, in New York two, and in Alabama three mining operations whose output in 1891 was between 200,000 and 500,000 tons.

Although iron ore in this country was first found in North Carolina, and iron was first produced in Virginia, the successful pioneer enterprise was in Massachusetts, in the year 1645. Most of the ore used was bog or pond ore, and one plant in Canada is still operated chiefly on this class of brown hematite ore. The following illustrates the way in which pond ores were obtained in Massachusetts in the year 1794:† "Vast quantities of iron, both cast and wrought, have been made in this part of the country for more than a hundred years past; but it was chiefly out of bog ore, until that kind was much exhausted in these parts. About the year 1747 it was discovered that there was an iron mine in the bottom of our great pond at Assowamset; and after some years it became the main ore that was used in the town, both at furnaces and forges, and much of it has been carried into the neighboring places for the same purpose. Men go out with boats, and make use of instruments much like those with which oysters are taken, to get up the ore from the bottom of the pond. I am told that for a number of years a man would take up and bring to shore two tons of it in a day, but now it is so much exhausted that half a ton is reckoned a good day's work for one man. But in an adjacent pond it is now plenty, where the water is twenty feet deep, and much is taken from that depth, as well as from shoaler water. It has also been plenty in a pond in the town of Carver, where they have a furnace upon the stream which runs from it. The quantity of this treasure, which hath been taken out of the bottom of clear ponds, is said to have been sometimes as much as 500 tons in a year." The average price of these pond ores was about $6 per ton, delivered at the furnace.

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* In 1892 three mining operations exceeded the output of the Cornwall ore hills.

† *Vide Volume of Manufactures; Tenth Census*, p. 798.

Nearly all of the iron ore mined in the earlier history of the iron industry was of the bog or pond varieties, and it was not until the commencement of the eighteenth century that any of the magnetic ores of New Jersey were utilized. The Dickerson Mine, which lately closed down, was one of the first mines of this character of ore opened, being located in 1716. The ore was often carried to the iron works in leather bags on pack horses.

Blast furnaces increasing in number and size required larger supplies of iron ore, flux and fuel, and to meet this it was necessary to employ other methods than those of dragging for iron. At first most of the mines were worked "open cut," but as the demands increased it became necessary to work underground so as to avoid heavy stripping, and danger from slides. There are, however, numerous open cut mines wrought at present and some large underground operations are being transformed into open cuts. The pick and the shovel, while still used, are largely supplemented by the steam, air or electric drills, and in some cases by steam shovels. High explosives have displaced much of the ordinary powder, and the wagons or carts drawn to the surface by horses or mules are to a great extent superseded by hoisting appliances operated by steam-power or by compressed air, and in place of ore carried in wagons or on pack saddles, we have the rapid and cheap transportation by the various steam railroads to supplement that by water. The harder red specular ores, which were first mined in Michigan in 1847, owing to low water transportation rates and the high percentage of iron they contain, came rapidly into favor, and it may be of interest to draw a comparison between the pond ore exploitation described above and one of the modern iron ore mines of the Lake Superior district.

At the Chapin Mine at Iron Mountain, Mich., the ore is taken from four shafts, ranging from 300 to over 600 feet in depth, and from an open pit of over an acre in area. The fourth shaft was sunk through a stratum of quicksand, and in order to pass this, a circle of iron pipes was driven and connected with a refrigerating machine. This reduced the temperature of the contents of the pipe to about zero, freezing the quicksand, and, keeping it frozen, this was then drilled and blasted like rock. The machinery of the mine is run chiefly by means of compressed air, although there is ample boiler capacity to operate the entire plant in case of accident to the compressor plant. This compressed air is carried a distance of three miles in wrought-iron pipe 24 inches in diameter. The Quinnesec Falls furnish, under a head of about 52 feet, the water to three 48-inch and one 54-inch turbine. There are three pairs of 32-inch diameter and 60-inch stroke, and one pair of 36-inch diameter and 60-inch stroke compressors. This compressed air is the motive-power for the hoisting plant and also for more than 100 power drills. The number of employés varies from 1,800 to nearly 2,000. The ore is found in four large lenses, and is broken down by means of power drills and high explosives, loaded on mine cars, taken to the shafts, hoisted to the surface, where a cable conveys it to the trestle, on which the cars are automatically dumped into railroad cars or taken to the stock pile, from which the ore is afterward loaded on railroad cars by means of a steam shovel. By this means a twenty-ton car has been loaded in four minutes. As much as 2,700 tons of ore have been hoisted from one shaft in twenty-four hours, and in one year over 700,000 tons were mined.

[*To be continued.*]

PHILADELPHIA'S SHARE IN THE DEVELOPMENT OF PHOTOGRAPHY.

By Mr. Julius F. Sachse.

[*A lecture delivered before the Franklin Institute, December 16, 1892.*]

The lecturer was introduced by the Secretary of the Institute and spoke as follows:

Mr. President, Members of the Franklin Institute,
Ladies and Gentlemen:

It is well-known to most persons that photography is, with the exception of the art of printing, the most widely disseminated art-science throughout the world.

Within a few decades, modern photography has penetrated into every quarter of the known world; and the vast space within the limits of the lately explored ice cap of Greenland to the tropical jungles of equatorial Africa, has been conquered and brought into subjection in the interest of general information by the modern dry-plate and the perfected lenses of the present day.

It is but a little over half a century, or, to be exact, just fifty-three years ago, when the first account of Daguerre's process reached America by the slow and uncertain methods of communication of the day. And when the news arrived it was published, only to be received by nearly everyone with suspicion and ridicule; and the whole matter was set down by scientist and scholar as another grand hoax, similar to the one sprung upon the scientific world a few years before in connection with Herschel's great telescope.

However, the doubt and uncertainty were soon dispelled by a member of this institution, after which the development of the process was rapid and steady.

Although it is but a question of half a century, few persons at the present day are aware that photographic portraiture is a Philadelphia invention, or how great is Philadelphia's share in the development of photography, and that the present perfect state of universal photography was brought about mainly by Philadelphia investigators and experimenters, their efforts being fostered by two of Philadelphia's scientific institutions; the first of these, the American Philosophical Society, the oldest and then most active and important scientific society in America; the other one, though in its comparative infancy, lacked none of the vigor of its more mature rival, and now after an active life of almost three-fourths of a century stands as an acknowledged scientific centre in the world. I allude to the Franklin Institute.

Daguerre, after the first promulgation of his process, and the vote of a pension by the French Chamber of Deputies, never did anything towards the improvement of his invention. It was left to the experiments of others to give the process a practical and commercial value.

To a Philadelphia scientist is due the improvement to Daguerre's process as originally promulgated, which made its universal application possible, and in reality forms the basis of the whole photographic structure of to-day. I have reference to the application and use of bromine as an accelerator by Dr. Paul Beck Goddard, of Philadelphia.

In connection with this subject, I will advance the following claims for Philadelphia in the development of photography, viz:

(1) That Joseph Saxton, of Philadelphia, made the first heliograph in America, October 16, 1839.

(2) That Robert Cornelius, of Philadelphia, and a member of the Franklin Institute, obtained the first picture of a human face ever taken by Daguerre's process, November, 1839.

(3) That to Dr. Paul Beck Goddard, of the faculty of the University of Pennsylvania in Philadelphia, belongs the honor of the discovery of bromine as an accelerator, December, 1839.

(4) That Dr. Paul Beck Goddard, of Philadelphia, was the first person in the world to obtain an instantaneous picture by heliography, December, 1839.

(5) That William G. Mason, of Philadelphia, obtained the first perfect picture in the camera by aid of artificial light, December, 1839.

(6) That the first portrait studio in America, or more strictly in the world, was opened in Philadelphia, February, 1840, by Robert Cornelius, at the northeast corner of Eighth Street and Lodge Alley.

(7) That the first heliograph ever entered for exhibition was one by Dr. Joseph E. Parker at the tenth exhibition of the Franklin Institute, held in October, 1840, at the old Masonic Hall, in Philadelphia.

(8) That Joseph Saxton, of Philadelphia, in 1841, produced the first photo-mechanical reproduction for use with printer's ink, which combined in its production the daguerreotype, electrotype and a mechanical process.

(9) That the first successful attempts at interior photography were made by Dr. Paul Beck Goddard, January, 1840, at the Academy of Natural Sciences, at the southeast corner of Twelfth and Sansom Streets. The originals are still in existence.

I will further state the daguerrean portraiture had actually ceased to be a novelty in Philadelphia long before the process was even introduced elsewhere in this country, or was practised in Europe.

To establish this fact, it is but necessary to refer to the *Public Ledger*, of October 12, 1840, where in the account of the tenth exhibition of the Franklin Institute, then in progress, it states:

"Throughout the room are various specimens of the daguerreotype. They consist chiefly of miniatures."

The first authentic account of Daguerre's process to reach America was a letter written in Paris and sent to Alexander D. Bache, a member of the Philosophical Society and of this Institute. This letter, which embodied the whole secret, then first made public, was published in the *United States Gazette*, September 25, 1839, with an introduction in which it was stated that some steps of the process are not explicable by known laws. This account set forth the crude process of Daguerre, as first publicly announced to the Chamber of

Deputies, in Paris, August 19, 1839. It was republished in the *Journal of the Franklin Institute*, for September, 1839, without a word of notice or comment. This was followed in the next *Journal* (October, 1839, p. 287), with an account from *Galignani* of three street scenes in Paris, taken from Daguerre's atelier, which were exhibited before the Chamber of Deputies at a meeting subsequent to the one held August 19th.

Notwithstanding these repeated notices of the heliographic process, no action whatever was taken upon the subject by any scientific institutions, the published accounts thus far being looked upon as unworthy of serious consideration.

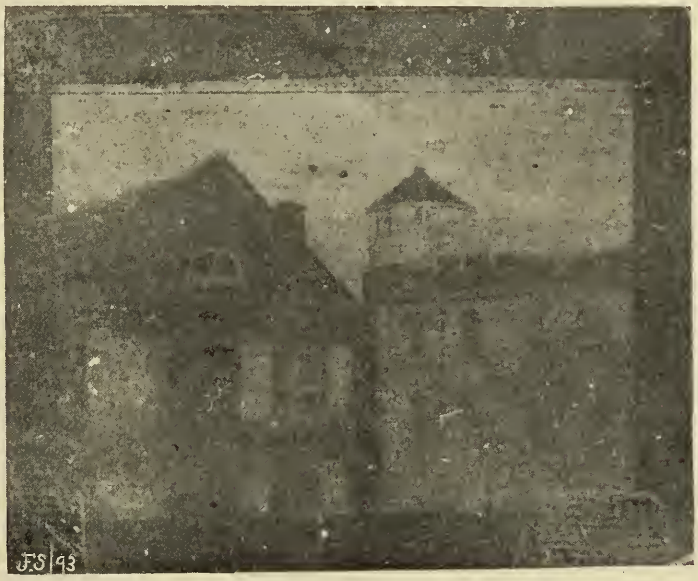
A few weeks later, however, a more detailed account reached America; this was from an eye-witness, who was a special correspondent of the *New York Star*. It was published October 14, 1839, and gave an account of the public demonstration given by Daguerre on the 17th of September at the Grand Hotel, on the Quay d' Orsay.

So skeptical were the Parisians of Daguerre's claims, and so great was the popular opposition to the grant made by the deputies to the inventor, that to silence public clamor the Minister of the Interior ordered Daguerre to give three public demonstrations of his process so that the interested public might judge whether the deputies were justified in pensioning Daguerre for the disclosure of his process.

This account was reprinted in the *American Daily Advertiser*, October 16, 1839. So crude was Daguerre's method, as shown by this account, that the time occupied to produce this single picture was one hour and twelve minutes.

Among those whose notice was attracted to the publication of Daguerre's process was one Joseph Saxton, an attaché of the United States Mint in this city, a man of culture and great scientific accomplishments. When Saxton read this account as published, it seemed so clear and feasible, that he at once concluded to try the process according to the directions set forth in the newspaper.

A cigar-box was improvised as a camera, while an ordinary burning glass, consisting of a convex lens, was fixed in one end and made to do duty as an objective. A pasteboard seidlitz-powder box, containing some flakes of dry iodine, and a cut-out in the lid somewhat smaller than the plate answered the purposes of a coating box. For a mercury bath, the ingenious experimenter mortised a block of hard wood, attaching underneath a globular bottom of sheet iron, so as to hold the quicksilver and allow the application of a spirit lamp beneath. A piece of polished silver ribbon, such as coin blanks are cut from, served in lieu of the copper plates.

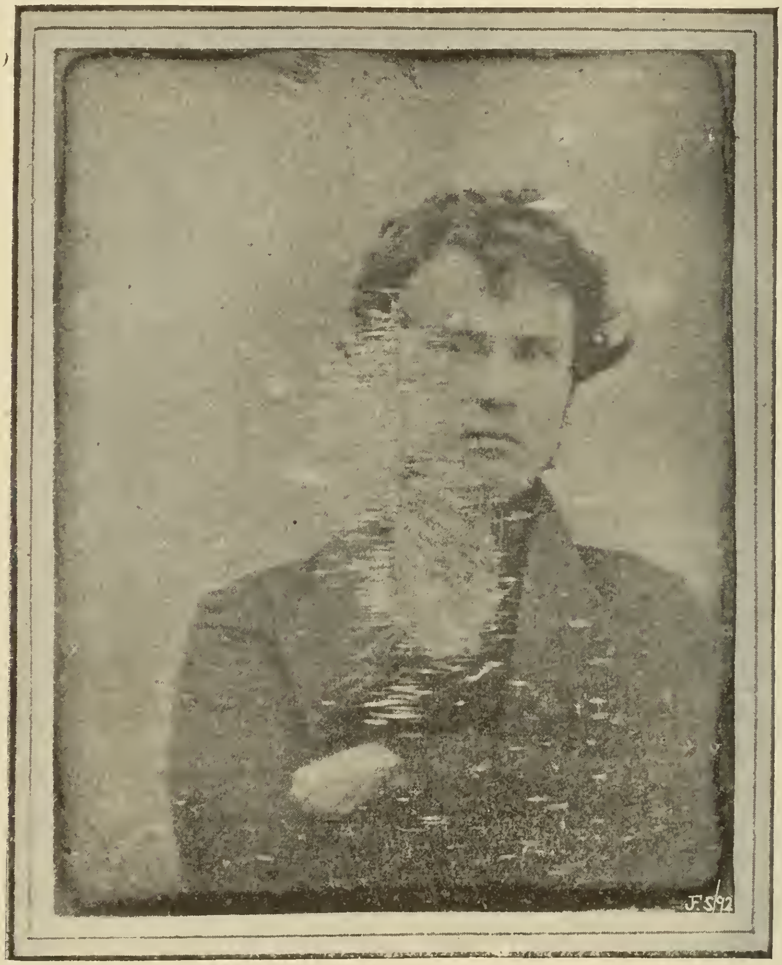


Fac-simile of the first daguerreotype (heliograph) made in America, by Joseph Saxton from window of Mint, October, 1830.

When all these preparations were completed, the ingenious Saxton set his apparatus on the window-sill of one of the second story north windows of the Mint, and pointed it northeastwardly toward the sunlit buildings beyond. After the exposure, the instructions in the newspaper were followed to the letter amidst the ridicule of the other attachés who were present, but, to the great surprise of the latter, and the joy of the experimenter, the attempt resulted in a perfect picture. There, permanently impressed upon the silver plate, was the picture of the old Philadelphia High

School and the State Arsenal, which then stood upon the site.

Joseph Saxton had proved the truthfulness of the published account of Daguerre's invention, and had made the first heliograph in America. On the next day, Saxton succeeded in making several other pictures of different buildings, all of which were taken from the same window.



Fac-simile of what is believed to be the first portrait ever made by the daguerreotype process. Taken by Robert Cornelius, in Philadelphia, November, 1839.

To Robert Cornelius, of Philadelphia, is due the honor of having produced the first successful portrait of any living person by the Daguerre process. This was accomplished in the yard back of his store and residence, (old) 176 Chestnut Street, above Seventh (now number 710), in Philadelphia.

How Robert Cornelius, who was a lamp-maker and a metal-worker, became interested in Daguerre's invention, is best told in his own words to the speaker, viz:

"Mr. Saxton, who was then connected with the United States Mint, had the opportunity of receiving an early notice of the manner in which Daguerre was operating. He soon produced a picture from the second story of the Mint—a view of chimneys and tops of houses. He was anxious to continue the experiment and called upon me, and showed his experiment, explained to me the manner of doing it, and desired me to prepare some plated metal to experiment with. With pleasure I complied with his request. It was our business to make a great variety of articles of plated metal. Very soon afterwards, I made in the factory a tin box, and bought from McAllister, 48 Chestnut Street, a lens about two inches in diameter, such as was used for opera purposes. With these instruments I made the first likeness of myself and another one of some of my children, in the open yard of my dwelling, sunlight bright upon us, and I am fully of the impression that I was the first to obtain a likeness of the human face."

In a subsequent communication in reference to this picture, Mr. Cornelius writes, viz:

"You will notice the figure is not in the centre of the plate. The reason for it is, I was alone, and ran in front of the camera after preparing it for the picture, and could not know until the picture was taken that I was not in the centre. It required some minutes with iodine to produce the effect."

This achievement of Robert Cornelius, a member of this society, is all the greater when it is considered that at that time, in Europe, it was considered impossible to apply the Daguerrean process to the production of portraits; for, with the chemicals and apparatus there employed, no picture could be taken in less than about a quarter of an hour, and as the correctness of a portrait produced by this art depends upon perfect immobility during the whole sitting, the mere idea of such an application of photography was looked upon as altogether absurd.

This statement will be found in the *Franklin Institute Journal*, vol. x, p. 50.

Unfortunately the exact date of this successful experiment at portraiture has not come down to us, nor is Mr. Cornelius able to recall it with certainty. That it was not long after Saxton s experiment is, however, proven by the fact that one of the pictures was shown by Robert Patterson, a director of the Mint at the regular stated meeting of the American Philosophical Society, December 6, 1839, and the fact is so recorded upon the minutes (*Proc. A. P. S.*, vol. i, p. 155).

It was not until a month later that the first French daguerreotype reached America. This was obtained in Paris by Mr. Henry Seybert and sent to the Philosophical Society in Philadelphia, and was shown at the regular meeting, January 3, 1840 (*Proc. A. P. S.*, vol. i, p. 169).

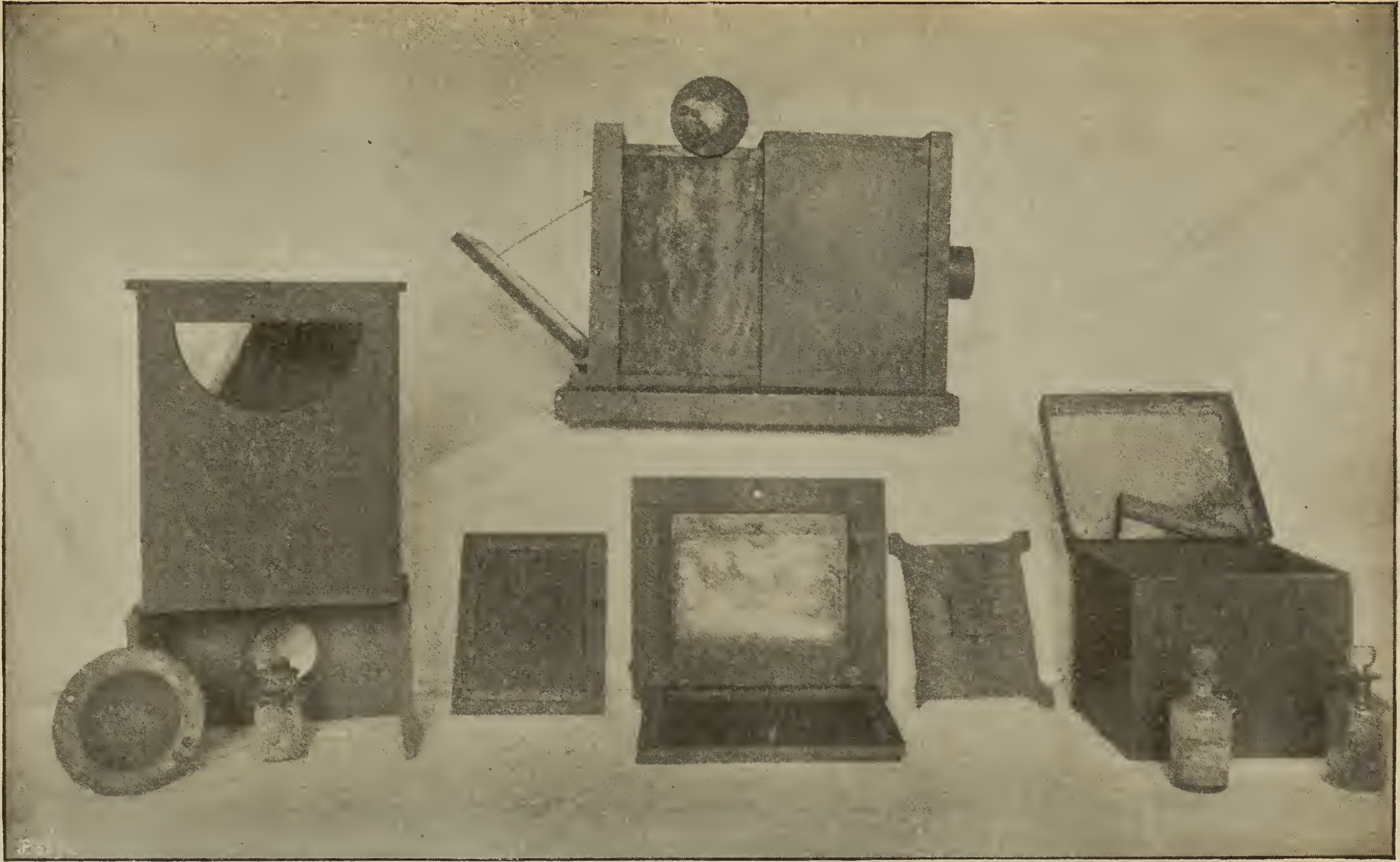
A comparison with Saxton's early efforts showed that they were equal, if not superior, to the French specimen, while Cornelius' and Goddard's efforts were far in advance of the French production.

The month of December, 1839, was destined to prove a memorable one in the development of the heliographic art.

It was during this month that the most important improvement was made upon Daguerre's process. This was the application of bromine as an accelerator, by Dr. Paul Beck Goddard, of Philadelphia. It was this discovery which solved the question of time exposure, perfecting Daguerre's process and thereby making possible its universal application in the various arts and sciences.

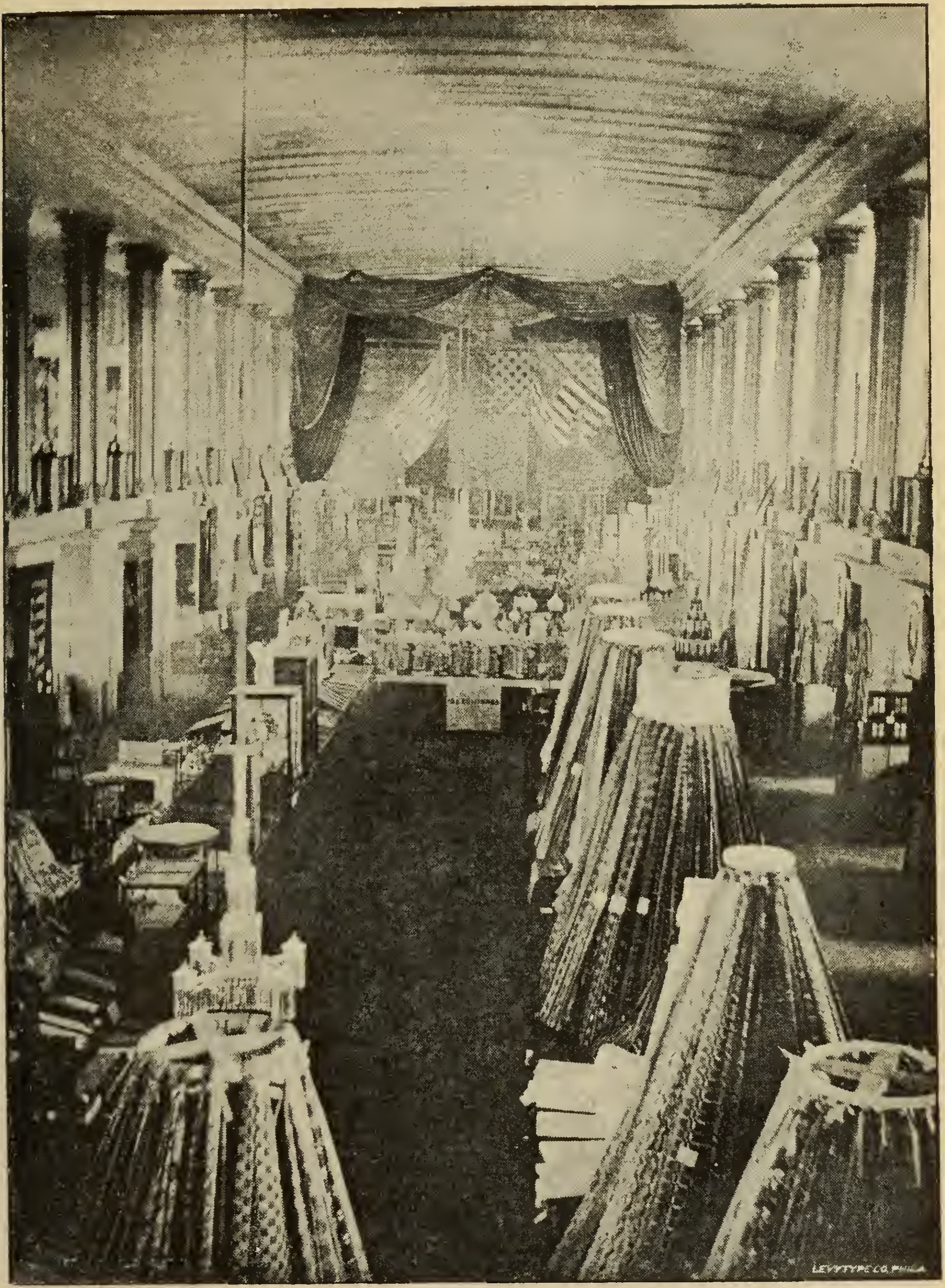
The proof of Dr. Goddard's claim to priority in the use of bromine is to be found in the *Proceedings of the American Philosophical Society*, vol. iii, p. 180.

The experiments of Dr. Goddard, in December, 1839, resulted in the production of a perfect specimen by the use of bromine, and was subsequently shown at the Philosophical Society. It was during this series of experiments with bromine that Dr. Goddard succeeded in obtaining several good views instantaneously in the open air, which were the first instantaneous pictures ever made by any heliographic process.



STUDIO OUTFIT OF DR. PAUL BECK GODDARD, PHILADELPHIA, 1840.

Lens and Shutter.
Camera with body extended, showing mirror set for focus-ing.
Fuming box ready for use, with glass to view process during development.
Plate holder, with original coated plate open for exposure.
Coating box, with rake to distribute chemicals on tray.
Diffuser for Vapor.
Iron Mercury bath.
Brass spirit lamp
Tray chemicals used in coating plates.
Mercury bottle.
Iodine bottle.



The eleventh annual exhibition of the Franklin Institute, held at Chinese Museum, N. E. corner Ninth and Sansom Streets, October, 1842. Daguerreotype by Dr. Paul Beck Goddard. Negative from original by Julius F. Sachse.

The First Studio.—Spurred on by his success in experimental portraiture, Robert Cornelius, together with Dr. Goddard, devoted considerable time to heliographic experiments, and the application of the process to portraiture. These progressed so satisfactorily that early in the year 1840 Mr. Cornelius secured the second story room in the building at the northeast corner of Eighth Street and Lodge Alley (now Jayne Street) above Chestnut. This was arranged exclusively for daguerrean portraiture, thus making it the first heliographic studio in the world.

The method employed to concentrate light upon the sitter consisted in a series of reflectors, set at different angles, together with the use of blue glass to screen the sitter. The time for a sitting averaged about one minute. It is an interesting fact that the first apparatus, such as the camera, plates, mats, coating boxes, etc., were all made by Mr. Cornelius personally. The lenses he obtained from McAllister, the Philadelphia optician.

In connection with this subject I have here a copy of the first successful studio picture, the father of the speaker, taken by Mr. Cornelius in his new establishment.

The original is a representative specimen of his skill and proficiency, and its perfect condition at the present day attests the permanency of his early efforts.

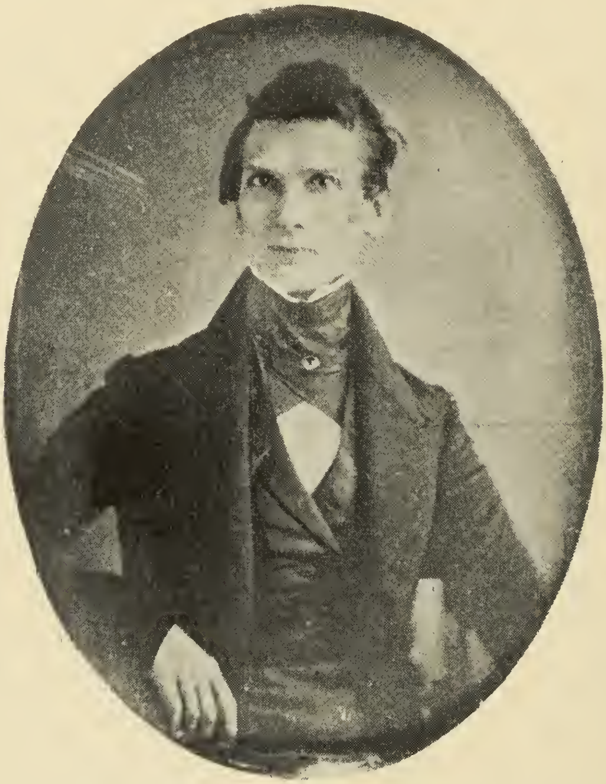
Considerable success attended Mr. Cornelius, a leading feature being an increase in the size of the image. Thus on March 6, 1840, we again find a notice of his progress chronicled in the *Proceedings of the Am. Philosophical Society.*

"Dr. Patterson exhibited some specimens of the heliographic art (daguerreotype) of a large size, executed by Mr. Robert Cornelius, of Philadelphia, and stated to the society that Mr. Cornelius had succeeded in obtaining beautiful representations upon highly-polished silver plate." (*Proc. A. P. S.*, vol. i, p. 181.)

Mr. Cornelius' enterprise attracted much attention among the wealthy and scientific classes, and brought many sitters to the establishment.

An interesting item for the professional photographer of to-day who furnishes a dozen cabinets for $1, or who turns out thirty-six tintypes for a quarter, is, that so great was the rush for the daguerrean miniatures, as they were called, that prospective sitters had to be "booked" a week ahead, at $5 for each sitting. Each received his day and hour, subject, of course, to sunshine. No sittings were attempted in cloudy weather.

About a year after the "atelier," at Eighth and Lodge Alley, was established, Mr. Cornelius removed his establishment to larger quarters on the south side of Market Street. His announcement in the *Public Ledger*, of July 1, 1841, reads, viz:



Fac-simile of the first successful studio portrait, made by Robert Cornelius, 1840.

"*Daguerreotype Miniatures.*—R. Cornelius respectfully announces that he has resumed the taking of daguerreotype miniatures, and invites the public to call at his rooms, No. 270 Market Street" [now 810], "where specimens of the art can be seen. The recent improvements are such that miniatures can be made in the shade and without regard to the state of the weather."

The last positive record we have relating to Cornelius as a professional heliographer is the entry upon the minutes of the stated meeting of the American Philosophical Society April 15, 1842, stating:

"Mr. G. W. Smith presented some daguerreotype portraits made by Mr. Cornelius by an improved process, an important part of which was the greater polish given to the plate, and the absence of cross lines."

The splendid results obtained by Cornelius, Goddard and others in Philadelphia, gave the art-science that impetus which has since placed it among the indispensable arts of the present day.

Another application of the heliographic art, which has now reached enormous proportions, viz: that of mechanical reproductions for printing purposes, is also due to Philadelphia scientists. The first photo-mechanical reproduction ever made was one by Joseph Saxton, to illustrate a Philadelphia book in the year 1841, viz: Eckfelt and DuBois' *Manual of Gold and Silver Coins.* It is a view of the Mint, and appears on the title-page. We reproduce a copy herewith.

Commenting upon it, the authors state:

"To obtain the vignette of the Mint (which is on the title-page), as there was no medallion to rule from, it was required to go back to the original, and this necessarily brought into play another brilliant invention of modern times, the daguerreotype. A picture of this edifice was taken with this instrument by Mr. Saxton, from which a copy was engraved in soft metal by Mr. Gobrecht; from this copy a counterpart was obtained in copper by the electrotype, and therefrom the engraving was effected. This view is therefore commended to the reader, not only as a faithful transcript of the original, but as combining in its production three discoveries which adorn the present age, the daguerreotype, electrotype and machine engraving."*

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* *Manual of Gold and Silver Coins*, Philadelphia, 1842, p. 189.

The first published record of interior photography appears in a notice of a series of views taken of the thirteenth exhibition, held October, 1844, at the Chinese Museum. For some reason the Institute Committee failed to take any notice of these views; not so, however, with the reporter of the *Ledger*, wide-awake as the news-gatherer of the present day. A note was made of the novelty and on October 25, 1844, appears the following notice, viz:

"In the southwest corner of the gallery, W. & F. Langenheim have their daguerreotype apparatus, with a number of excellent specimens of their work. They have several daguerreotype views of the exhibition, taken from favorable points, which look very well, and are, of course, accurate, but unavoidably left-handed."

As early as the next year, 1845, the Messrs. Langenheim made some excellent instantaneous views of America's greatest natural wonder, Niagara Falls; specimens which for beauty of finish and execution have never been surpassed. Copies of this effort were sent to Daguerre, to the President of the United States, and to various crowned heads of Europe.

In return Daguerre sent the following characteristic note, one of the few written by him in the first person and signed by his name:

À Monsieur le Consul de France à Philadelphie.

MONSIEUR:—I profit with great satisfaction by the return of Mr. Martin to America to thank you for your kindness in sending me the charming view of Niagara, which is due to the amiable attention of Messrs. Langenheim. Besides the merit of these proofs of execution they have also the merit to represent one of the wonders of the known world.

I beg of you sir, to be my interpreter with the Messrs. Langenheim by tendering them all my gratitude.

I repeat to you sir, my thanks, and I pray you to accept this expression of my regards.

DAGUERRE.

Bry-sur-Marne, le 30 Juin, 1846.

The King of Saxony complimented the Philadelphia daguerreotypists by sending a note of thanks and a medal.

Frederick of Prussia accompanied his thanks by the great gold medal for art.

The King of Wurtemburg also sent a gold medal.

Queen Victoria through Lord Aberdeen, sent the following note:

> I have now the pleasure to acquaint you, that, although it is a general rule with her Majesty not to receive presents from any quarter, her Majesty has been graciously pleased to accept this view of the falls of Niagara and express her admiration at the great skill with which it has been taken.
>
> [SIGNED] ABERDEEN.

We now come to the next period, which marks the greatest advance in the history of the photographic progress, viz: the advent of glass negatives and positives, first applied to lantern slides and stereoscopic views, in the development of which none hold a more honorable position than Francis Schreiber and the two Langenheim brothers. The same may be said of the printing of positives from glass negatives.

In substantiating this claim for Philadelphia, I will quote from the *London Art Journal*, for April, 1851, p. 106, a report which was written by no less an authority than Robert Hunt: "Our attention has been especially excited by some specimens of photographic positives on paper, from glass negatives, which will be exhibited in the Palace of Industry (they are from Philadelphia), to which the inventors have given the names of hyalotypes. In the hyalotype, both the positive and negative impressions are obtained on glass, and the result is as near an approach to perfection as we can imagine. The hyalotype is the invention of Messrs. W. & F. Langenheim, of Philadelphia—these gentlemen state 'We have substituted plate glass for paper in the negative, and also in the positive altering the process to suit the new material.'"

Robert Hunt continues and says:

"The most interesting application of this discovery is the construction of magic lantern slides, taken from nature by the camera-obscura, without the aid of pencil or brush." Hunt then goes on to describe some of the specimen slides, nearly all of which were local Philadelphia subjects, such as "The Spring Garden Hall," "The U. S. Custom House." There was a total of 126 views and portraits in this collection. He further states that the colors of these pictures also show a peculiarity in the process of the Messrs. Langenheim. We have them of a rich warm brown, a deep sepia and many of them intensely black, showing that the art of toning was known to these Philadelphia artists long before it was practised elsewhere.

At the great London Exhibition of 1851, the Philadelphia heliographers were awarded the medal over all competitors, a fact of which they were advised by an autograph letter of Millard Fillmore, the President of the United States.

These same artists were also the first to attempt the publication of a series of stereoscopic views of American scenery.

In connection with this venture the following card appeared in the *Public Ledger*, during December, 1855:

Langenheim's New Series of American Stereoscopic Views.—We, the undersigned, who by subscribing and furnishing F. Langenheim with the means to commence a new series of American stereoscopic views between Philadelphia and Niagara Falls, have received the number subscribed for, and take pleasure in expressing our entire satisfaction with them, and would recommend them to all who have a desire to cultivate a taste for their own American works of art and skill. They are also colored with much taste and truthfulness to nature.

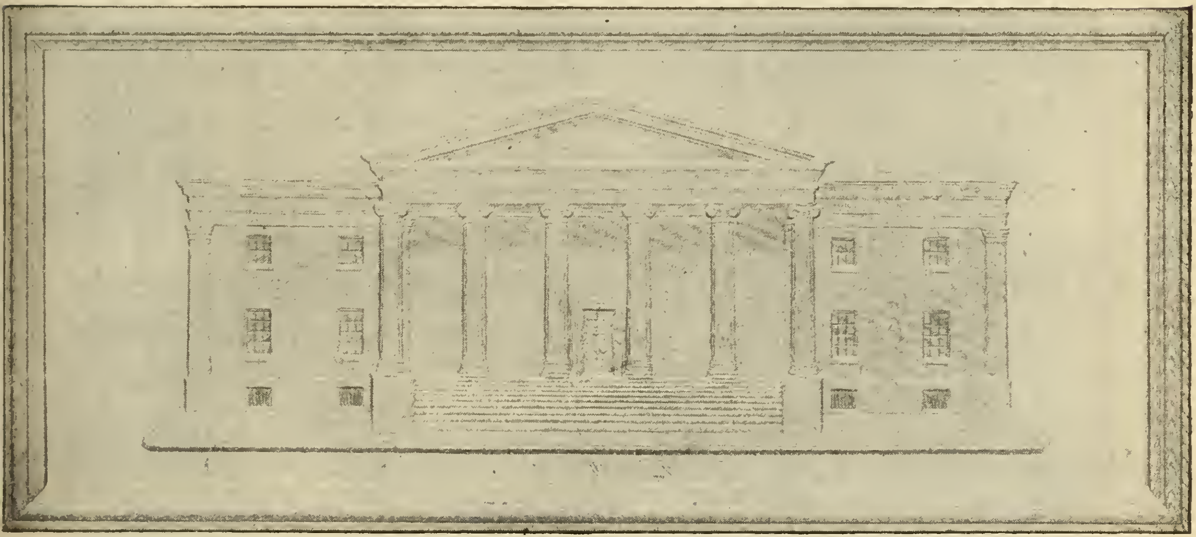
JOHN TUCKER,
R. D. CULLEN,
H. J. WILLIAMS,
CHARLES VEZIN,
JAMES FARNUM,
JAMES R. GRAVES,
M. J. LEWIS,
C. GULLUC,
J. H. TOWNE,
FAIRMAN ROGERS,
THOMAS C. KIRKBRIDE, M.D.
SAMUEL SLOAN,
J. C. CRESSON,
LYON J. LEVY,
JOSHUA BAILY,
SAMUEL MASON,
JEREMIAH HACKER,
THOMAS C. JAMES,
JAMES L. CLAYBORNE,
CHARLES C. GRUGAN,
M. L. DAWSON.

"*A Card.*—The new series of American stereoscopic views alluded to in the above testimonial were taken in company with the subscriber upon a recent trip to Niagara Falls along the south route of the Reading, Catawissa, Williamsport and Elmira Railroad to the Falls, with the addition of about twelve very interesting views of scenery in the coal regions near Pottsville on the Mine Hill Railroad.

"These pictures are soon to be published upon glass and porcelain by an entirely new process. They are also to be published in a cheaper form upon albuminized paper, and may be had at the publication office of William Lloyd, 188 Chestnut Street, Philadelphia.

"The paper views will be sold in book form, and ready for sale on Friday at Cowperthwaite & Co., under the Masonic Hall, and Parry & McMullan, Fourth and Chestnut. (December, 1855.)"

A complete set of these early views of Philadelphia, either in hyalotype, lantern slides, or stereoscopic prints would be of great interest at the present day. An earnest search by the speaker, however, has failed to bring to light any but a few scattering specimens of Langenheim's scenic efforts.



The first photo-mechanical reproduction. Made by Joseph Saxton, 1841.

I think that sufficient has been shown in the preceding remarks to prove that Philadelphia scientists from the very start have played an important part in the development of the photographic art-science, and that our fair city may well be called the birthplace of photographic portraiture as well as the mother city of modern photography.

In the development of the dry-plate industry Philadelphia also stands in the advance, the first commercial dry-plates in America having been made in this city. The reputation of Philadelphia dry-plates and films are known throughout the photographic world.

In scientific research, it is but necessary to mention the names of M. Carey Lea and Frederick E. Ives, both I think members of this Institute; the latter being the inventor of the well-known half-tone process which bears his name, and more lately of a method for the projection of views in the colors of nature by strictly photographic means.

That in our generation the artists and professionals of our city have not deteriorated, is shown by the splendid achievements of Gutekunst and others of lesser renown, all proving themselves photographic artists second to none in the country.

In connection with my subject, I will also call attention that the first negative of a flash of lightning ever taken was made by Mr. W. N. Jennings, a member of this society, September, 1882, proving the fact that the electrical discharges from the clouds were wavy and not zigzag. This peculiar branch of scientific photography since its feasibility was shown by Mr. Jennings has developed into a wide-spread study. One of the most interesting results obtained by Mr. Jennings is the proof that lightning is oscillatory in character, by a series of fine photographs taken from a moving train, while crossing the prairie of North Dakota last summer.

In conclusion, I will call your attention to a few of the earliest heliographic experiments, contrasting them with the latest advances of the present period; these specimens will show the great strides which have been made during the past half a century.

LIST OF SPECIMENS REFERRED TO IN THE LECTURE AND EXHIBITED.

(1) Fac-simile of Saxton's first effort at the Mint of the United States, October, 1839. Original deposited with the Historical Society of Pennsylvania.

(2) Contrast. An Ives heliochromoscope, showing the latest and highest development of the photographic art in the reproduction of the colors of nature.

(3) Fac-simile of the first portrait of the human face by any heliographic process, made by Robert Cornelius, November, 1839.

(4) Comparison: a portrait of the present day, made by Fred'k Gutekunst.

(5) Fac-simile of the first studio portrait, by Robert Cornelius, February, 1840.

(6) Fac-simile of the first instantaneous local views ever placed on exhibition or for competition, by Joseph E. Parker, March, 1840.

(7) Specimen of the earliest daguerreotype by the use of bromine, by Dr. Paul Beck Goddard, December, 1839.

(8) Fac-simile of the first photo-mechanical reproduction, made by Joseph Saxton in 1841.

(9) Specimen of the latest development of the photo-mechanical processes.

(10) Specimen daguerreotype for which Philadelphia became renowned, by Marcus A. Root.

(11) Specimen of earliest paper negative made by Francis Schreiber, Philadelphia, 1847.

(12) Contrast: a negative on flexible celluloid film.

(13) Specimen of photography or talbotype made from a paper negative about 1847. This is one of the earliest efforts at positive photography.

(14) Photograph, view of Fairmount Water Works. One of the earliest positives made from a glass negative. Made for exhibition at the World's Fair, London, 1851.

(15) Portrait of Joseph Saxton.

(16) Portrait of Frederick Langenheim, a talbotype from paper negative.

(17) Portrait of Francis Schreiber, the veteran photographer and co-worker with the Langenheim Brothers, at the age of ninety-one years.

(18) The complete studio outfit of Dr. Paul Beck Goddard, as used by him in 1840.

CAUSES OF FIRES.

By C. John Hexamer.

INTRODUCTION.

In a lecture delivered before the Institute, in 1884, I called attention to the "annual fire waste" in our country, as follows:

"When we consider that in the year 1883 about $100,000,000 worth of property was destroyed by fire throughout the United States, and if losses continue at the present rate they will this year [1884] amount to $128,000,000, we must admit that the study of fires and their causes is of intense interest and of the greatest practical value. For the sums just quoted are so great that the mind cannot conceive them; it is only by comparison that we can arrive at an approximate idea. Let us suppose that a clerk was counting off single dollar notes for the payment of these losses, and that he could count at the rapid rate of 100 in a minute; it would take him 2·43 years to complete his task, without a moment of sleep or rest. Or suppose I placed $1 notes representing the amount of this annual fire waste in line lengthwise, edge to edge; it would form a line of greenbacks 7,893,333·3 feet long; or, to express it in miles, a strip 1,494·9 miles in length.

"All of the former huge amount of property has literally been blotted out of existence. Whether the losses were borne by the insurance companies or by individuals, the result is the complete extermination of just so much wealth which was created by human effort and ingenuity. The world is poorer by that amount than it would have been could these fires have been avoided.

"A person who considers these facts and figures thoughtfully must be impressed with the conviction that the existing means of preventing and extinguishing fires are either very inadequate or very greatly neglected.

"The whole matter will have to receive more consideration in the future than has hitherto been given to it. Civilized society, which leans so much upon human industry, cannot afford to permit vast quantities of the fruits of industry to be blotted out every year, when preventives are within reach."

Matters since that time have not improved, and taking up any insurance periodical, or report, the same lamentations are found in their perusal.

I have before me an address by President George E. Wagner, of the Philadelphia Fire Underwriters' Association, made November 18, 1892, where, in his usual lucid, incisive manner, he speaks of the fire losses in the United States, saying:

"With the increasing wealth of the country, the amount insured increases correspondingly. It has already reached the enormous aggregate of nearly sixteen thousand millions under outstanding policies. Of course, there must be an increase in the number of burnings and the amount of fire losses. It is true they are enormous, the annual ash heap costing the nation about $100,000,000. About $70,000,000 of this amount was last year paid through the insurance companies; that, however, does not alter the fact that the expense to the nation is the whole amount of the loss sustained by reason of the fires, for the companies collected the amount they paid from the holders of their policies in the shape of premiums.

"How to decrease this stupendous destruction is a problem well worth the thought and effort of the statesman, the economist and the business man. Think of it, $100,000,000 per annum of value annihilated! Some through ignorance, some through carelessness, some through criminality, and but little comparatively through natural or non-preventable causes. All statistics of 'fire origin' clearly illustrate my meaning, for 'causes' stated therein, show that the great majority of fires are *preventable*, but we repeat that this destruction is a direct loss of the wealth of the nation, every dollar paid by the insurance companies comes out of the policy-holders, and not out of the coffers of the companies or the pockets of the stock-holders. The owners of the companies pay in a certain capital as a guarantee for the fulfilment of their contracts, for which the capital is liable. If the receipts of the companies are insufficient to pay the losses and expenses, the capital is impaired, and the law compels the companies to retire from business. Hundreds of companies have been compelled to do this in the past few years, and more must, unless present methods are changed."

I do not wish to mince matters, and therefore state at the outset that the object of this series of articles is to reduce the number of "*preventable*" fires. I will attempt to give the causes of fires in our habitations, and *pari passu*, in our commercial and manufacturing enterprises. In other words to write a short fire technology. Of course, I will be forced to repeat much that I have written in insurance and other technical journals, but which is brought forth here for the first time in what I shall attempt to make a succinct and continued account of my own and the combined experiences of underwriters and inspectors, as far as I have been able to collect them in practice, and from a close study of the literature of the subject and personal interviews.

I may perhaps be able to still more forcibly impress the general importance of the subject about to be treated by giving a few extracts from remarks I made on the occasion of the twenty-first anniversary of the insurance journal, *The Spectator*, in 1889 (printed in full in the anniversary number):

"The more we study the causes of fires, the more surely may we hope to reduce their number. For several years I have attempted to show to the readers of *The Spectator* how easy it is to prevent spontaneous combustion, explosions and fires from many other causes, by exercising a small amount of care. If we know how fires are produced in a certain process of manufacture the problem is solved. All that is necessary is that the insurer and the assured, through constant vigilance, see that at no time conditions may arise which, by the unalterable laws of nature, will ultimately cause a fire. * * *

"It is exceedingly difficult to get people to change their accustomed usages, but it can be done through the services of efficient inspectors, and the reiteration of principles during frequent reinspections made by competent officials. But do we know all the underlying principles, the laws of nature, that cause fires? To this question we can only answer with an emphatic no; and those who know most of the causes of fires, know best, to use an Hibernianism, how little they actually do know. In order to discover a law of nature, or prove an hypothesis we must be able, by combining the conditions which we think produce fire, experimentally, to actually produce the results we anticipated: if not, our hypothesis was wrong, and we must seek a different solution. What is most wanting in our profession are men who will devote their life to the discovery, and the experimental proofs of the causes of fires. There are enough intelligent men who can be taught the principles, when once established, and who could be told to look for this or that when inspecting a risk [the thing insured] of a certain class, and who would perform their duty faithfully. But not all the principles have been studied, and new and dangerous processes are daily introduced which should be intelligently investigated. These investigations must, however, in our country be carried on entirely through private means, and for the sake of the love the investigator bears to his subject. As the pay of experts and inspectors is comparatively small, it is beyond him, unless he has independent means, to erect a laboratory where such tests could be made, and to carry on experiments which might prove of great value." * * *

[A testing laboratory of this nature, open to competent persons, under proper restrictions, in the proposed "*new*" Franklin Institute building, for which we are still *waiting*, I hope not in vain, for "hope deferred maketh the heart sick," would no doubt result in much good work.]

"Much credit is due the New England mutuals for the excellent labor they have done in this respect; and the money they have thus expended on this specialty has yielded manifold returns. There has of late been a decided improvement in this respect by the stock companies who, through their boards and associations, have been able to do much. The public, instead of battling and crying out against such combinations, should most earnestly support them, as it is through their efforts alone that the intelligent and careful assured will in the course of time (through schedule rating) be emancipated from the tax of indirectly paying for the losses of the idiotic and careless. That which we frequently call an accident, I must repeat, is very often caused by the imperfect knowledge of materials and natural laws. * * *

"The prospects for the future are not bright, If we wander about an 'improving' city, we must soon reach the conclusion that the fire hazards of large cities are increasing. Without speaking of manufactories, let us for a moment consider that most prized store or mercantile insurance. The first floors of stores, as now built, consist of almost one large window on at least one side; or, if situated at a corner, two sides of the first floor consists of windows. The ultra is reached (several cases in Philadelphia) where the buildings are located at the triangular insersections of three streets, and the entire first floor consists of windows, the building resting on iron piers. If an old corner house is to be transformed into a store, the outside walls on the first floor are torn out, iron piers are inserted, and the wall above rested on iron girders. The modern lavish use of glass and iron has and will still further increase the terrible fire waste to which our country is annually subjected. We can in almost every large city in the Union find great buildings in which we vainly search for one good piece of wall in their entire front, being constructed of iron columns, posts, girders and sheet iron. How are these to withstand the heat of a fire? And how are we to calculate what is a fair distance for exposure, when in a city with a good paid fire department (by means of this glass and iron construction) fires have been transmitted over streets sixty-feet in width. But, more curiously, what shall we say of the building department which allows the building to be rebuilt much higher on iron stilts (filled out with glass) on the first floor? And, most curiously, what shall we think of the companies who had paid for the old building, who again insure this new and worse building, putting at nought the old adage 'that a burnt child dreads the fire?' Consider, if you can, the disproportion between the construction of such a building and the amount of inflammable material stored in it. Then the amount of care usually exercised in regard to the paraphernalia of lighting, heating, accumulation of rubbish, etc.; then consider that entire rows of such risks exist, and we must admit the outlook for the fire underwriter is not bright. What we need in most cities are better building laws, formulated or revised by committees of intelligent underwriters. We cannot expect merchants to spend large additional sums of money for safer buildings when they are not forced to do it either by insurance companies or municipal regulations. * * *

"If we look into one of these tinder-boxes filled with inflammable stuffs, we are often shocked at the manner in which fires, gas, etc., are used, the lighting of gas and the paraphernalia of heating being intrusted to boys. * * *

"I shall at some future time speak of the accumulation of hazardous materials in large cities, the way in which they are stored and handled, and how they should be stored. In considering in detail all this, and the numerous violations of what even good common-sense would dictate, and further consider that our means of extinguishing fires do not increase in the same ratio with the increase of fire hazards, we must confess that it is wonderful we have not more fire losses. But, fortunate as we are, how long can we afford to let things get worse? How soon will the day come when the business will be so unprofitable that capital will not invest in it? * * *

"The only remedies are:

(1) "Ascertain fire hazards. A national bureau, for tests, experiments, analysis of oils, special investigations, etc., would be but a very slight tax on the nation or even the united companies, and would bring the greatest returns, if the ascertained results are properly applied.

(2) "Better building laws.

(3) "Inspection and reinspection by faithful, competent, well-paid men. No ground floor inspections. A surveyor

who does not know in what condition the attic and the cellar of the house he inspects are, does not do his duty. Insert in survey blanks the questions: 'Is the scuttle supplied with a permanent ladder?' 'Number of lights in cellar, and how arranged?' and see to it that these questions are carefully and truthfully answered. Do not leave your inspections to unreliable persons because they are cheap. What proper inspection will do has again and again been practically demonstrated.

(4) "The co-operation of the press in instructing the public in these vitally important matters, in which it is even more ignorant than matters pertaining to hygiene.

(5) "Mechanics' erecting and heating and lighting paraphernalia should be as strictly watched, and the work inspected as rigorously, by a special municipal department, as the boards of health should look after sanitary matters.

(6) "The office of 'fire coroner,' filled by an especially well-trained expert, should be created in every city, whose sole duty it would be to investigate all fires, and make full reports on causes, etc. The position of fire marshal does not fill the bill."

When an epidemic threatens us, we are apt to inspect and improve our sanitary arrangements and look about for preventives, let us then also investigate the general causes of fire which continually threatens us. Annually, many persons are burnt to death through causes which could have been prevented, a state of things which is an insult to civilized society. Is it not remarkable that an age, wonderful for so many material achievements, has produced so little to prevent fires and save life in case of fire?

Of fires, as is the case in other investigations, it is most difficult to discover the origin. Before preventive measures against enemies of mankind can, however, intelligently be undertaken, be they epidemics or dangers of the elements, we must first know the causes which underlie the evil we wish to overcome. The investigator on this subject labors under difficulties which the student of no other subject encounters to a like degree. The student of a new disease may note the symptoms of a great number of cases, which he can diligently himself examine; we, on the other hand, receive our accounts from persons who observed what we most desire to know while excited and frightened, and often cases occur where all traces of the origin have been destroyed; while it is exceedingly difficult to obtain information from employés, which would reflect on their judgment, or criminate them.

In order to lessen the number of serious fires, not so much better means for extinguishing, but methods of preventing them are required; and fires can only be prevented by a proper understanding of fire hazards by all classes.

First, however, we must know a few general facts. And, as it is the intention that what is here said should appeal to laymen generally, these explanations are "popular," and will, perhaps, appear puerile to chemists.

What is Fire?—Before we go into details of how to prevent fires, let us first ask ourselves, What is fire? Webster defines it as "an evolution of light and heat in the combustion of bodies, or that active, natural process, by which burning bodies are decomposed with the evolution of light and heat;" this to laymen is rather a vague definition, and conveys to the mind no clear idea.

If we rapidly draw our hand through the surrounding space, we feel a certain amount of resistance. This resistance is due to a gaseous body which surrounds us on all sides, and which we term air, a substance known to the ancients, who tried to weigh it. As, for example, Aristotle filled a bladder and weighed it, then exhausted the air and reweighed the bladder, and actually believed he had thereby determined the weight of the atmosphere. It was not, however, until the advent of the experimental era under Galileo and Torricelli that its weight or pressure was determined. It was found at the level of the sea to be about fifteen pounds to the square inch.

This surrounding fluid consists of two gases, oxygen and nitrogen; not, however, chemically combined, but merely mixed in the proportion—in round numbers—of seventy-nine parts of nitrogen and twenty-one of oxygen. Nitrogen, which is fourteen times more dense than hydrogen, is a gas entirely negative in its qualities; does not support combustion, and its purpose in the air is merely to act as a diluting agent so as to make the effects of oxygen less violent. Oxygen, the great supporter of life and also the great destroyer in nature, is an odorless, colorless gas, sixteen times (density 15·95) as heavy as hydrogen. It and its combinations constitute the greater part of our earth. The crystalline rocks, which consist of silicates, contain from 48 to 44 per cent., by weight, of oxygen. Water, which is composed of oxygen and hydrogen, contains 88·89 parts, by weight, of oxygen. It is this element which causes almost all those phenomena which we ordinarily term combustion. Phenomena which it causes while ordinarily diluted with nitrogen (air) are greatly intensified when the element is pure; and even metals, such as iron and steel, when ignited in a globe filled with oxygen, burn with brillant scintillations.

We are now ready for the question, "What is combustion?" It might be defined as a chemical union of oxygen with some other element or elements, accompanied by an evolution of light and heat, while similar unions of other substances, not with oxygen directly, might be termed "chemical combination." Substances which unite with oxygen are termed combustible substances, while oxygen is a supporter of combustion. These terms, although but relatively correct—as combustion might be defined as an act of any chemical union accompanied by an evolution of light and heat—are for our purposes very convenient and will be retained throughout.

It has been found that before a substance can ignite (take fire) in either the air or oxygen, a certain temperature must be reached, and this necessary temperature is termed the ignition point or temperature of ignition. While for some substances this point is very low, for others it is extremely high, as, for example, nitrogen will only unite with oxygen at the intense heat of the electric spark; while phosphorus burns slowly at 10° C. (50° F.), as may be noticed in the dark (phosphorescence); it does not burn brightly until heated to 60° C. (140° F.), and zinc ethyl and phosphuretted hydrogen ignite in the air at the ordinary temperature.

But most bodies do not unite with the oxygen of the air rapidly enough at ordinary temperatures to produce light and heat, but must be heated for a production of active combustion. In the case of the decay of organic matter or the rusting of metals oxidation goes on slowly, producing heat, and the total amount of heat that a decaying log produces in the long time required for its destruction is exactly equal to the amount of heat produced by its rapid oxidation (burning) in a stove. We, therefore, distinguish between quick and slow combustion.

The temperatures of different flames vary greatly. Bunsen found that the temperature of the flame of hydrogen burning in air is 2,024° C., temperature of a hydrogen flame burning in oxygen 2,844° C., carbonic oxide 1,997° when burning in air, and 3,003° C. when burning in oxygen.

In order to measure the quantity or strength of a material or force, we must have a measure or standard of comparison. The standard for the measurement of heat, if the expression be allowed, as heat is a force and not a material, is the "thermal unit," the amount of heat required to raise the temperature of one gram of water 1° C. This measure is now almost universally employed by scientists, although the old English caloric unit, the amount of heat required to raise one pound of water 1° F., is yet sometimes employed. Two other units are also used: in Germany, the amount of heat required to raise one kilogram of water 1° C. is much used; while the unit of one pound of water to 1° C. is sometimes employed.

Numerous experiments, made by different scientists, have proved beyond a doubt that a constant quantity of heat is given off when the same weight of the same substance burns to form the same products of combustion, whether the combustion proceeds slowly or rapidly. Numerous measurements of the amount of heat disengaged by the combination of different substances with oxygen have been made, of which those of Andrews, Julius Thomsen, Favre and Silbermann are the most nearly correct. The following tables, compiled by Roscoe, show the heat of combustion in thermal units for one gram of substance burnt:

COMBUSTION IN OXYGEN.

One Gram of	*Thermal Units.*	*Observer.*
Charcoal,	7,273	Lavoisier.
	7,167	Dulong.
	7,912	Depretz.
	7,714	Grassi.
	8,080	Favre and Silbermann.
	7,900	Andrews.
Diamond,	7,770	Favre and Silbermann.
Natural graphite,	7,811	Favre and Silbermann.
Gas carbon,	8,047	Favre aud Silbermann.
Hydrogen,	34,462	Favre and Silbermann.
	33,808	Andrews.
	34,180	Thomsen.
Sulphur,	2,220	Favre and Silbermann.
	2,307	Andrews.
Phosphorus,	5,747	Andrews.
Zinc,	1,301	Andrews.
Iron,	1,576	Andrews.
Tin,	1,233	Andrews.
Copper,	602	Andrews.
Marsh gas,	13,063	Favre and Silbermann.
	13,108	Andrews.
	13,120	Thomsen.
Olefiant gas,	11,858	Favre and Silbermann.
	11,942	Andrews.
	11,957	Thomsen.
Carbon monoxide,	2,431	Andrews.
	2,403	Favre and Silbermann.
	2,385	Thomsen.

The importance of all this will become apparent when we begin the study of what are commonly known as "spontaneous combustions," but to conclude the facts with a brief statement:

Whenever a body combines with oxygen, chemical action takes place, and the transformed energy is shown in the form of heat; and if more violent, in the form of light; that is, combustion, or differently stated, *fire!*

After this rather lengthy preamble, I will ask you to take a journey through our homes, places of manufacture and amusement, warehouses and stores, studying in each the things we meet as we pass through, in relation to their likelihood of producing fire; and first of all, as "charity begins at home," we will study the causes of *fires in dwellings.*

[*To be continued.*]

RESISTANCE TO SHIP'S MOTION: A NATURAL LAW NEWLY DISCOVERED.

By F. M. F. Cazin.

[*Continued from p. 216.*]

Before entering on the task of rendering such proof, on which alone the acceptance of my equation can be demanded, I should state, that there was a time, when I inclined to the belief, that the facts underlying my equation were almost self-evident to such a degree, that they needed only to be stated, in order to be accepted even by the most critically inclined intellects. And only by actual test did I find out what inherent power belongs even with scientists to habitual course of thought or conception. And almost as an excuse for the thoroughness adopted here below in rendering proof, I shall quote some criticism, that my equation was met with, by even such men as are teaching mechanics in one or another of their branches of practical application at technical colleges on this continent.

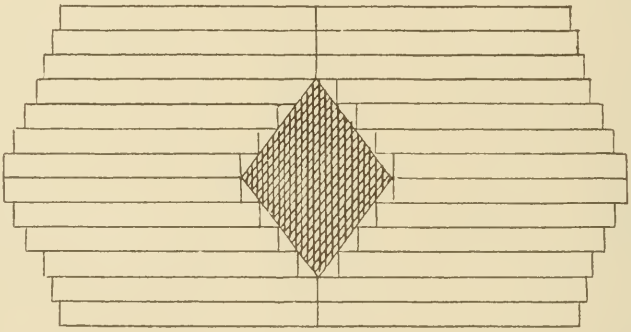
The one, when the question of displacement in inverse direction to movement of solid of the precisely stated quantity of the medium was submitted to him, at once undertook to declare the claim to be a fallacy, and to support his declaration, he did not rely on any mechanician of renown, as those hereabove quoted, but he substituted for their and my valuation a brand-new one of his own, that is for the movement of medium in inverse direction of the solid's progress an exclusively lateral movement of medium.

And in this opposing view the other learned professor at once concurred, and jointly they expressed themselves thus:

"Mr. Cazin has apparently overlooked the possibility of lateral displacement. That the displacement is lateral and not in a direction contrary to the movement of the solid, should be *self-evident*, but may be made clear by a simple illustration. Let us imagine a mass, in the form of a double wedge, forced through a pile of boards, which slide out of the way, as the wedge passes, and return to their original position, after it has gone by. These boards may be taken to represent thin films of water, which in like manner move out of the way laterally, as the solid passes.

"If the water be confined by the walls of a vessel, the various films will be increased in thickness, as the body passes.

"This increase in thickness is less, the larger the vessel, and *nil* in *unconfined* bodies of liquid. This thickening of the films represents a certain elevation of the water and a certain amount of work. This work is, however, returned, after the body passes, and the film resumes its original thickness.



"The lateral displacement of the water, apart from questions of friction, impact, inertia, etc., does not absorb any power, when the body in question moves in large bodies of liquid, permitting lateral and not vertical displacement.

"Mr. Cazin's error seems to us to be fundamental, and to vitiate his conclusions and results derived therefrom."

How modestly did Weisbach express in comparison with the claim of these learned savants, that their new opinion is "self-evident:" "We cannot specify the value of these resistances *a priori*," says he, "but we may assume, on account of the great similarity of conditions, that at least the general law for percussion by unlimited quantity of water does not vary from the law for the percussion resulting from isolated jets."

And, indeed, all that Weisbach claimed was and ever remained true, only that he did not fully solve the problem, as I claim, that based on this master mind's teaching, I now have solved it. But my adversaries of to-day pass over all learned predecessors, as if they never had existed. They build not on what these master minds prepared, as I clearly did, but they ignore them entirely.

To the trained mechanician I need not point out, that, if what my adversaries claim were true, it would solve the perpetuum-mobile conundrum.

At no time has there been offered a truer representation of the water jet flowing with the pressure or head (constant) proportionate to a given velocity, than is by me offered in my new equation, where the value for pressure or head (S) is borrowed from the old masters, and is made to answer the requirement of a true representation by making the other factor the precise quantity and weight of water, (relating to the same time unit [second] as the value v) that is active in causing the stated effect.

I must now ask my readers to favor me with their goodwill in making up by keen perception what my demonstration may be deficient in cleverness and transparency of expression.

IMMERSON OF SHIPS.

We all know that, when a ship is launched, and when subsequently she has come to rest, there is, so to speak, as the result of the proceeding, a cavity in the water, where there was previously none, and in the cavity so produced in the water the ship is resting. If the ship had been let go into a tank, and the walls of that tank had previously been marked for volume (for cubic metres) of contents, the launching of the ship would have caused the surface of the water to appear after the launching higher up than it was before. And the *increase in elevation of the surface multiplied by the area of surface would show the precise volume* of the immersed part of the ship. And the weight of the volume of water so measured would be precisely equal to the weight of the total ship, the ship weighing one metric ton for every cubic metre or one kilogram for every litre of water displaced by the ship in her immersion.

The value of "buoyancy" (= B) therefore reoresents the volume of the immersed part of the ship or her total displacement, *when at rest*, and, when such incipient displacement is expressed in metres, also the total weight of the ship in metric tons corresponding to cubic metres, or in kilograms corresponding to litres.

The word "tonnage" cannot well be substituted for the word "buoyancy," because by tonnage old usage understands loading capacity. It is this volume of water (= B,) which my readers will then know under the name "buoyancy," that I shall have eminently to deal with, and it becomes a necessity in dealing with this value as a volume, to find for it a form or shape equally *representative of all ships* as the value *buoyancy* itself is. The standard form to be selected should not only preserve all the essential or important characteristics of the forms of all ships coming under consideration, but should also in the same expression represent the different positions relative to the water and to the direction of her motion, that the ship may assume during such motion.

In the course of my research I found two dimensions for the volume "buoyancy" which, although new to mechanics and nautics, properly and appropriately described the volume and weight of medium displaced by first immersion, which latter value for valid reasons it will be proper to henceforth always designate as the *buoyancy* of the immersed or submerged solid.

These two dimensions or factors correctly describe the precise value of such *buoyancy* (B), and *buoyancy* divided by either must measure the other of the two dimensions, and both must describe *buoyancy* as a volume and form of uniform transverse section in its entire other dimension, in order to properly represent a uniform and continuous effect.

For ships in normal movement, their length measured on the water line would constitute the one of these factors $= d.$*

$$\frac{B}{d}$$

then must produce the other value ($= f$), representing a transverse uniform section of the ideal form for the value *buoyancy*, and this factor f may then properly and appropriately be called "transverse average section" ($= f$). And

$$B = d\,f \text{ and } \frac{B}{d} = f$$

In the old valuation of resistance to motion in submersion, the values a and b (face angles) were made dependent on length between these solid angles and the central transverse major section (Ms), and represented stable values leaving no possible mutability or adaptation of values to the different position, that the ship's body might assume relative to its movement. But the correct valuation of d (measured in the direction of motion) accounts for such mutation.

The value

$$f = \frac{B}{d}$$

then represents truly and correctly the comparative, continuous, uniform or permanent resistance to ship's motion, because such resistance at any stated moment is the same as in all other moments under the same conditions, and

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* While experimenting, it became soon evident to me, that the constructive length of the solid (for ships on water line), although analogous to the natural direction of its movement, would not be a proper dimension in describing an ideal form, by which the resistance to the motion of all or any solids as affected by the medium might be measured, but I found the value ($= d$) for the shortest line (for ships drawn in the plane of the water's surface) drawn in the direction of the relative motion, or a parallel with such direction, between perpendiculars on direction of motion, passing through the temporary extreme ends of the ship, to be adequate in describing the ideal form of solid Whether then the solid move in the direction of its greatest length or not, the values d and

$$\frac{B}{d}$$

would properly express the relation between volume and movement.

for equal lengths of time it is equal and constitutes a factor to the value, that relates to the stated time. And when a flow of water were under consideration, then this value f would be the area of action, the transverse section (current of the electrician*), and with the distance of flow per second as the other factor, the product would precisely give the quantity of water passing any stable point within such second. And this product would also state the precise mass of water, that with the proper factor for movement (impulse) in such mass would correctly specify the total kinetic effect of such moving mass per second.

None of these qualities or virtues possessed by the value f, that is, by "transverse average section," is attributive also to the value Ms, that is, to "transverse major section."

Were it not for this by me newly introduced value of "transverse average section," that is, of the volume divided by length, the accurate valuation of resistance to motion of solid in a medium would have remained impossible.

WHAT HAPPENS TO THE MEDIUM WHEN A SOLID MOVES IN IT?

If a steamer obtains her buoyancy by displacing 12,000 metric tons or cubic metres of water, and has a length of 200 metres, then her "transverse average section" (f) is as $B \div d = 12{,}000 \div 200$, or as sixty square metres.

I assume that this is the steamer just before-mentioned, of which I described the launching in the preceding lines, and that she is housed at the Cunard pier in North River, New York, ready to start on her voyage to Liverpool.

Where this steamer lies at her pier, there is, so to speak, a cavity in the water, which is filled with the lower part of the steamer's body. As we know the steamer's buoyancy (= 12,000 tons), we also know the precise weight of the water, which would fill that cavity, and which had to go *to the surface* of the bulk of the water, when the ship was launched and later on more thereof, when she received both her permanent and transient load.

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* Compare the author's series on "Electro-metallurgy." *The Electric World*, vol. xx, No. 10, September 3, 1892.

If we may imagine all the water around the steamer frozen solid (assumed without change of volume), and the steamer lifted out of the cavity in which she rested, then there would be precisely such a cavity in the ice, which to fill it would take the precise 12,000 metric tons of water, measuring precisely 12,000 cubic metres in volume (as water), which made the steamer's buoyancy.

For the sake of illustrating some other very important facts in the premises, let us suppose that the Cunards must move that steamer, in the ice, for a distance equal to her own length.

They would first be obliged to have a cavity cut at the new and adjoining place, and such cavity would be required of precisely the same dimensions as the one before described. And then they might get the ship thereinto as best they could. And when the job had been done, what would be the proper description of the work actually performed?

The medium being considered as only temporarily solid, in order to better illustrate changes in the position of parts thereof, I shall use this assumption exclusively for showing and demonstrating these changes in the position of parts of the medium, without as yet discussing the road, by which such parts of the medium perfect these changes in their position.

We should, after the removing of the steamer out of the cavity, in which she rested originally, into an adjoining equal cavity, situate on the line of her normal motion, have the following changes:

(*a*) The steamer in her new position, would have travelled over the distance *d*.

(*b*) A quantity *B* of (frozen) water had been taken out of the cavity, where the steamer now lies.

(*c*) There would be a cavity in the (frozen) water, where the steamer lay, before it made the specific movement, such cavity being in volume equal to *B*, and the water, which would fill this cavity would also be equal to *B*, or equal to the quantity removed out of the second cavity.

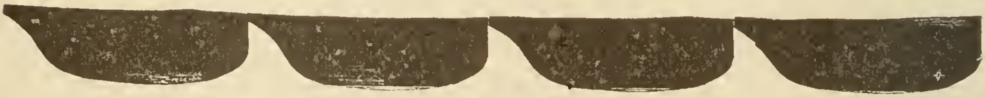
If then we assume this later quantity, which was removed out of the second cavity to be stored in the yet open first cavity, it will no longer be necessary to continue the spell of solidification for the medium water, because as a liquid even the changes as hereabove specified will remain undisturbed, until the ship move again.

The result then observed may properly and correctly be expressed as follows:

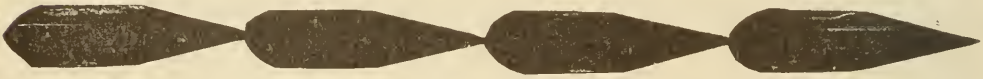
(1) In moving the distance *d* a ship causes a volume and weight *B* of the medium to be moved inversely to her own movement.

My illustration shows the result of three such removals.

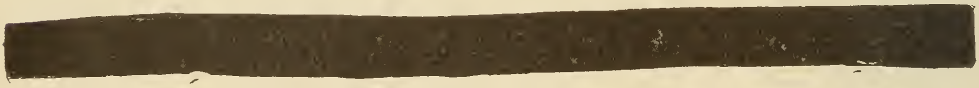
Had the ship, when frostbound, been actually and bodily lifted out of the cavity, in which she originally lay, and had she been removed to another more distant place, the ultimate results, as they were expressed under *a*, *b* and *c* would have remained in all but the distance of removal absolutely the same, and it may therefore be correctly stated, that



Vertical section of successive cavities.



Horizontal section of successive cavities.



Groove caused by continuous motion.

(2) The movement of a ship causes a movement of her own weight of the water (medium) in inverse direction, for the distance of her own travel.

Before finally dismissing the spell of solidification from our medium, water, we shall yet consider the effects of a sliding motion when brought about in the ice the same, as it occurs in the liquid water.

The effect of such sliding motion, which is the veritable motion of the ship in the water, will be more clearly shown, when both the real form of ship with non-uniform transverse section and the ideal representative of the same (immersed) volume, having a uniform transverse section, will be considered.

This ideal representative of the volume B of 12,000 cubic metres and of a length $= d =$ 200 metres must have a section f of sixty square metres. And in order to otherwise foster greater similarity, the section f may be assumed as an equilateral triangle, and if the density of the volume be assumed as $= 1$ for the total, with a larger portion of mass in one of the long solid angles, then this ideal body B will take a position in the water corresponding precisely to that of the ship.

Such a ship B of ideal form would originally lie in a groove-shaped cavity, and when an adjoining equal cavity be cut in the direction of normal motion, this ship may be caused to slide along for the distance d without any but the quantity B of the ice being removed, the total effects being exclusively those hereabove described under a, b and c.

But if the ship B had the usual shape combined with the same volume B and the same length d, non-uniform transverse sections, it would require a groove of such increased transverse section as the ship's transverse major section ($= Ms$) would call for, in order to let the ship slide in its groove. This would result in the necessity to remove temporarily in addition to the quantity B of the ice an additional quantity thereof being as d $(Ms - As)$, Ms standing for "transverse major section," and As standing for "transverse average section," the latter being

$$As = \frac{B}{d}$$

And the necessity of removal of this so defined quantity of the medium would be the result of form (shape) of solid exclusively, and it also would be of an entirely different character altogether, because it would not constitute a removal of a permanent character, but such removal would be temporary only, the portion of the um thus removed finding room, after the ship's progress at or in the precise location, where it was before, while the quantity *B* must actually be moved in inverse direction to the ship's movement and for the distance of the ship's travel, in order to find room below the level of the water's surface.

It has therefore been shown, that a real and permanent change of position of the quantity *B* only of the medium is caused by a solid's motion in sub- or im-mersion.

The quantity $d\ (Ms - As)$ of the medium falling back into its original position reproduces the force spent on its temporary removal, because the movement started (inertia, thus measured, overcome), this temporary (lateral) displacement and immediately following reoccupation of the original position is also practically continuous, simultaneous the one with the other, and uniform, the same as is the permanent continuous displacement of medium in inverse direction, that results from the movement of the ship.

It therefore follows, that in valuation of the total displacement of medium directly, inevitably and effectively caused by the movement of a solid in submersion, this complement $d \times (Ms - As)$ need find no place, and that the permanent displacement of medium in inverse direction to motion of solid alone produces the resistance to such motion.

Having utilized the assumption of the medium being temporarily frozen solid, in order to unmistakably show, that the movement of the solid in a medium really causes the removal of the quantity *B* of the medium in inverse direction to the movement of the solid, for each distance $= d$ that, the solid itself travels, we may now abandon this assumption. But the conclusion must be drawn from what has been shown, that a quantity of the medium $= B/d \times D$ ($D =$ distance of travel) is moved in inverse direction of the solid's motion for a distance $= d$.

It then remains to consider the movement of the ship (or of a horizontal column of the same submerged volume, but of uniform transverse average section) with the assumed solidification of the medium removed. This transmutation back from ice to water leaves the stated quantities of the medium whether solid or liquid in their relative positions, the *road only* by which these quantities changed their positions mutually presumably were different, had we dealt with water and not with ice. Actual displacement in inverse direction to motion by a solid moving in a medium can no longer rationally be denied, and the road only, on which the medium travels backward, for changing position, whether it be a direct one or an indirect one, or one by substitution in part or in total, this road, the road by which the medium travels backward, remains to be determined.

I may then be permitted at the hand of the information thus obtained, to describe the effect of the solid's motion in the "liquid" medium. It is not claimed, that the identical drops or molecules of the water in total fall back into identical relative positions in the cavities to be filled one after another. The water in its total mass is subject to mutation in position of parts all tending to the maintainance of its hydrostatic equilibrium, but so much is claimed only as is essential, namely, that the stated quantity of the medium changes position relative to the moving ship inversely to her motion.

When the ship moves ahead, the stated quantity of water, which is to move from head to stern, is being displaced continually at the precise, same rate in front, that room is made for it astern, and it must and will take the shortest possible road for its change of position, as an absolute consequence of its quality as a liquid for re-establishing thereby the hydrostatic equilibrium, which was disturbed through the ship's motion.

In the case of the ship, as we are accustomed to construct her, the water slides along the curves of her sides, a movement easily ascertainable in practical navigation and having in the case of screw-propellers a name even, as "propeller suction."

We know the precise quantity of water so moved by the ship's motion in inverse direction thereto, but we also know by the instrumentality of the same law, the precise, complementary quantity of water causing a lateral swell and falling back into its previous position.

The question, whether non-uniformity of transverse section results also in non-uniformity of back flow of medium and of resistance overcome at different stages of motion might be raised. The conditions to resistance remain constantly the same, therefore resistance itself must be uniform. Therefore the solid's uniform transverse average section,

$$\left(=f=\frac{B}{d}\right)$$

being uniform for all times and distances of motion, can alone truly represent the uniform distribution of resistance over all moments of motion. Is it therefore clearly shown and fully demonstrated, as heretofore stated, that:

(3) A solid moving in submersion a distance ($= d$) equal to its own length, measured in the direction of motion, displaces of the medium in inverse direction, for the distance of its own length a volume of the medium equal to its own immersed or submerged volume, ($= B$) and when moving any other distance moves the volume B of the medium, for the distance of such travel in inversed motion to its own motion.

And on this foundation the entire new system of valuating resistance to submerged motion can be built up by mathematical evolution.

I do, nevertheless, consider it as opportune to yet describe one other easy and very interesting method for proving displacement in inverse direction of measurable quantities of the medium by the movement of a solid in submersion, which can be applied by all, and which leaves no further room for scepticism to the most critical but unprejudiced mind.

[*To be continued.*]

PROCEEDINGS

OF THE

CHEMICAL SECTION

OF THE

FRANKLIN INSTITUTE.

[*Stated meeting, held Tuesday, March 21, 1893.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, March 21, 1893.

Dr. Wm. H. Greene, President, in the chair.

The special committee appointed to prepare a memoir of the late Dr. F. A. Genth presented, through Dr. Keller, an elaborate paper, embodying an account of the life and scientific work of the deceased, including a complete list of all the papers published by him. The paper was referred for publication in the *Journal of the Institute*, and on motion the committee was discharged, with the thanks of the Section for the thorough manner in which it had discharged its duties.

A letter of resignation from Mr. A. T. Eastwick was read, and on motion the resignation was accepted.

A bill amounting to $38.38 from the Institute for expenses of postage, etc., incurred in connection with sending out notices, and for the work involved in the separate binding of the volumes of Proceedings for 1892, was read, and on motion was referred to the Treasurer for payment.

Dr. Wahl, as conservator of the Section, reported that he had in his possession fifty-two copies of vol. i, ninety-seven copies of vol. ii, eighty-two copies of vol. iii, and forty-five copies of vol. iv of the Proceedings of the Section, and in reply to his inquiry as to what disposal should be made of them, the Section voted to leave them in his hands to dispose of in the interests of the Section in such manner as his judgment might dictate.

Dr. Wahl then read a paper, which was the joint production of himself and Dr. Greene, on a "New Method of Reducing Metallic Oxides."

It was received with much interest by the members present, and after some discussion by Dr. Hall and Dr. Wahl was referred for publication. Specimens of the products of the process were exhibited.

The Section then adjourned. WM. C. DAY, *Secretary.*

ON PHENOLPHTHALEIN AND METHYLORANGE AS INDICATORS.

By Mary Bidwell Breed.

[*Read at the stated meeting of the Chemical Section, held February 21, 1893.*]

In using phenolphthalein as an indicator in alkalimetry, there are certain precautions necessary that have not been sufficiently insisted upon in the literature of the subject. The following experience, however, will show the necessity for great care in its use.

During the standardization of a hydrochloric acid solution against normal caustic potash, phenolphthalein and methylorange were both used as indicators; and it was observed that, while with methylorange 20 cc. of the acid required only an average of 19·443 cc. of the alkali for neutralization, with phenolphthalein the same amount of acid required an average of 19·765 cc. of alkali, a difference which would introduce a considerable error. The same results were obtained with phenolphthalein, even when the solution was heated to boiling, and so it was believed that carbon dioxide could not be the cause of the discrepancy. That the source of the difficulty lay with the phenolphthalein, and not with the methylorange, seemed probable from the fact that it took more alkali to bring the color of phenolphthalein than to discharge that of methylorange; and also from the fact that, while the amounts of alkali used with the former varied from 19·65 cc. to 19·8 cc., those used with the latter were practically constant, differing only by 0·025 cc. Nothing could be found in the literature of the subject that threw any light on the problem. Fresh solutions, prepared with great care, gave analogous results, and after many fruitless attempts to explain the discrepancy, it was concluded that traces of carbon dioxide, dissolved by the alkali, must after all be the source of error. This would explain matters; for acid potassium carbonate, which would be formed in the solution during titration, is neutral to phenolphthalein, but alkaline to methylorange; and, therefore, as part of the alkali had been rendered neutral to phenolphthalein, it would take more of the solution to affect that indicator than to affect methylorange. This explanation was proved to be correct by prolonged, hard boiling of the solution, when using phenolphthalein. Alkali was titrated with acid, in this case, and it was found that, by boiling ten minutes or so after the end point had been apparently reached, the color could be made to reappear, and that it continued to reappear after each addition of acid until the amount of acid used was exactly equal to that used with methylorange. As the end point was approached, longer and longer periods of boiling were necessary after each drop added. A single titration never took less than an hour.

In view of this, a word of caution seems necessary. It is never safe to use phenolphthalein unless the solution is known to be absolutely free from carbon dioxide, or unless it is boiled long and thoroughly after the end point is apparently reached. As it is nearly impossible to keep a solution of caustic alkali entirely free from carbon dioxide, a titration with phenolphthalein is often as tedious as a gravimetric determination.

Phenolphthalein is probably used at present more extensively than any other indicator, but these objections make it desirable to adopt something more reliable and convenient. Methylorange is not affected by carbon dioxide, and when a sufficiently dilute solution is used, its end point is sharp. It has been found very satisfactory for sensitiveness and accuracy, and it is therefore strongly recommended wherever it is possible to use it.

CHEMICAL LABORATORY,
BRYN MAWR COLLEGE, PA., January, 1893.

DISCUSSION.

MR. HAINES suggested that the glass beaker may have been attacked by the boiling alkaline solution, resulting in extraction of alkali from the glass, especially if the boiling was continued as long as an hour. Such action has been observed even with Bohemian glass. The glass is stated to be generally attacked as a whole. As regards phenolphthalein and methylorange he wished to call attention to the statement by R. T. Thomson, in his comprehensive papers on indicators (*Chemical News*, **47**, 123, 184, and **44**, 32, 38, 119), that phenolphthalein has five times greater delicacy or sensitiveness than methylorange. In other words, in 100 cc. of distilled water, the former requires but 0·1 cc. of excess of deci-normal solution, while the latter requires 0·5 cc. of excess to produce the full change of color. In solutions of normal strength the difference is scarcely noticeable. He showed that this difference was not due to carbonic acid, but to the interference of neutral salts of sodium potassium, and ammonium formed during tritration, which affect the delicacy of methylorange, but not phenolphthalein, except in the case of salts of ammonia. Neutral salts of calcium, barium and magnesium have the same effect upon methylorange. Mr. Haines said that in recently making some determinations, requiring the use of both of these indicators, he had found the above statement as to this difference to be correct. A fresh standard solution of sodium hydrate, made from metallic sodium and carefully protected, gave practically the same results as an old solution of ordinary sodium hydrate in white sticks. In determining alumina volumetrically in sodium aluminate by the method described by Lunge (*Jour. Soc. Chem. Industry*, 1891, p. 314), in which both indicators are used and the amount of alumina is calculated from the difference of results of titration, Mr. Haines obtained results which agreed very closely with gravimetric estimations in the same solutions if the above correction for difference in delicacy of indicators was applied. Generally, methylorange is used only in a cold solution, but Lunge has shown that in estimating alumina volumetrically with methylorange, the solution should be heated to 30° to 40° C., but not exceeding the latter temperature. The action in the cold solution is too slow and the alumina is apt to be underestimated. Only dilute solutions of alumina should be used.

Phenacetolin also is a more delicate indicator than methylorange, being similar in this respect to phenolphthalein. In estimating calcium, magnesium and sodium carbonates, as in Hehner's method of determining hardness of waters, Mr. Haines has found, as others have also, that phenacetolin is preferable to methylorange, but in this case the former must be used hot, the latter cold. He finds that the alcoholic solution of phenacetolin keeps very much better if it is not filtered from the insoluble residue found in the article as sold.

Mr. Haines has also experienced some difficulty in obtaining the true methylorange (helianthin). Sutton incorrectly describes it as of a bright orange-red color; Allen states it is orange-yellow. An article of bright orange-red color sold in this country as methylorange gave the *reverse* of the correct colors with acids and alkalies and was so wanting in delicacy as to be practically worthless.

The article recently obtained from Bullock & Crenshaw, which agrees nearly with Allen's description, he had found to be perfectly satisfactory.

MR. HENRY PEMBERTON, Jr., remarked that in titrating with phenolphthalein and with methylorange as indicators, different results would be obtained if the standard alkali contained alumina. This impurity is not infrequently present in sodium or potassium hydrate. Even a small amount of alumina [*about* 0·002 grams] will require when methylorange is used 1 cc. of $\frac{N}{10}$ acid more than when phenolphthalein is used.

In regard to titrations with phenolphthalein in the presence of ammonium salts, J. H. Long has shown* that correct results are obtained when the solution is kept cold, and a sufficient quantity of the indicator is employed.

PROF. E. S. KEISER, in reply to Mr. Haines, said that while according to R. T. Thomson, methylorange was not as sensitive as phenolphthalein, other observers had found it to be more sensitive. For example, J. Wieland (*Berichte d. Deutschen Chem. Gesell.*, **16**, 1989), found that from three to four times as much of a $\frac{1}{100}$ normal solution was required to bring about the change of color with phenolphthalein as with methylorange. That is the phenolphthalein is less sensitive than the methylorange. Experiments made in the speaker's laboratory indicated that methylorange when used in the proper dilution was fully as sensitive as phenolphthalein. The great objection, however, to the use of phenolphthalein in ordinary titrations is its sensitiveness to carbon dioxide, and that it is neutral to acid carbonates. For example, R. B. Warder (*American Chem. Journal*, **3**, 55) has shown that alkaline solutions of this indicator can be decolorized by shaking them with air, and that by simply breathing upon the red liquid the color is discharged. The phenolphthalein is not colored by acid carbonates. Mr. Haines would find in the paper by R. T. Thomson, to which he refers, that that author distinctly states that when alkaline hydroxides containing alkaline carbonates are titrated and phenolphthalein is used as indicator, the color disappears when the hydroxide is neutralized and the carbonate changed to acid carbonate. That if the solution is then boiled the color reappears because the acid carbonate is decomposed, and more acid must be added and the titration continued until the color no longer appears in the boiling solution.

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* *American Chemical Journal,* **11,** 84.

As it is almost impossible to prevent standard alkali solutions from absorbing carbon dioxide from the air, it is evident that the strength of such solutions will constantly change if the determinations are made with phenolphthalein as the indicator. On the other hand, if the titrations are made with methylorange as the indicator the results are in no way influenced by the amount of carbon dioxide that has been absorbed. Hence, in all ordinary work it is advisable to use methylorange.

PROCEEDINGS
OF THE
ELECTRICAL SECTION
OF THE
FRANKLIN INSTITUTE.

[*Stated meeting, held Tuesday, February 28, 1893.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, February 28, 1893.

Mr. Elmer G. Willyoung, President, in the chair.

Present, thirteen members and visitors.

The minutes of the previous meeting were read and approved.

The Treasurer reported the cash balance in the treasury, and presented bills for printing, etc., which were approved and ordered paid.

It was moved and carried that in future the annual volumes of the Section's Proceedings be sent to members of the Section, but to non-members only on the joint order of the President and Secretary.

Mr. Robert H. Laird was elected Secretary and Treasurer of the Section, for the unexpired term of Prof. L. F. Rondinella, resigned.

Mr. Geo. F. Stradling was unable to present his paper on "The Migration of the Ions," on account of illness, which prevented his attendance.

Mr. Carl Hering made some interesting remarks on "The Smashing Point of Incandescent Lamps," with blackboard illustrations. Taking the decreasing efficiency of a lamp into account, and the correspondingly increasing total expense per candle-power per hour, he showed from the results of Professor Thomas' tests of American lamps, that it would be most economical to renew the lamps after running them 400 or 500 hours. The subject was discussed by Messrs. Pike, Rondinella, Billberg, Winand and Willyoung and other interesting points in connection with incandescent lighting were brought out.

Mr. Carl Hering presented a list of all the electrical journals published in the English, French and German languages. Referred for publication.

Upon motion, the President appointed a committee, consisting of himself and Messrs. Hering and Pike, to arrange for the entertainment of members at the meetings of the Section.

Adjourned. L. F. RONDINELLA, *Secretary.*

SOME PRINCIPLES THAT MUST BE OBSERVED IN ORDER TO MAKE A GOOD CLOSED-CIRCUIT BATTERY, AND A NEW PORTABLE DRY CELL DESCRIBED IN WHICH THESE PRINCIPLES ARE APPLIED.

BY E. F. NORTHRUP.

[*A paper read before the Electrical Section, Dec. 28, 1892; Jan. 24, 1893.*]

[*Continued from p. 237.*]

Porous Partitions.—A full discussion of porous partitions and terminals is too special for the limits of this article, for each style of cell requires some particular device. If the terminals are in contact with the electrolyte they must, of course, be of the same potential, not necessarily of the same material, as the electrode to which they are attached. Thus, a platinum wire fastened to carbon will cause no appreciable local action. As stated above, the best results will be obtained when the carbon electrodes are so constructed that they will serve a double function of porous cup and electrode. In all cases a porous cup should be avoided where it is possible, for it is so much dead resistance in the cell.

The Seal.—The seal for a small dry cell is one of its most important parts and one not so very easy to construct well. It is astonishing what deterioration and changes time will work upon a battery. In fact, the time test for a battery, as for most things, is an extremely important one. "Will it last?" is the pertinent question, and the way this must be answered depends not a little upon the security of the seal. A warning, however, is easier to give than a remedy, as the many patents taken out for seals alone will go to prove. The expansions and contractions that take place with changes of temperature are almost certain, sooner or later, to produce an opening through which the contents of the cell will creep and cause its final destruction, unless the seal be well constructed. The neophyte inventor cannot give too much attention to this apparently insignificant feature of a closed battery.

Secondary cells have largely taken the place of primary batteries which are designed to supply much current, but the demand for small portable cells has been rapidly increasing and nothing is likely to be invented which can replace them. Such cells are required by the physician to run his induction coils, and something of the sort is an absolute necessity for use in Wheatstone bridges and portable testing sets. Considering the very extensive demand for a small, compact and efficient dry battery, it is very surprising that the market is not better supplied. There are only two kinds now offered for sale which have any value whatever. They are both very expensive and must ever remain so, as they employ a silver salt for the depolarizer, and their electro-motive force, furthermore, is very low. Now, for the testing of resistance, especially high resistances, a high electro-motive force is required in order to make close measurements. If the resistance of the total circuit is great as compared with the internal resistance of the battery, the deflections of the galvanometer before a balance is obtained in the bridge are practically proportional to the total electromotive force of the batteries. Hence the number of batteries required is inversely proportional to their electromotive force. For testing work then, a cell with a volt and a half is just fifty per cent. better than a one volt cell. Cells employing a silver salt give at the most only 1·13 volts and average but about nine-tenths of a volt. A high electro-motive force is not the only requisite. A cell should even for test work have less than forty ohms internal resistance and for the running of induction coils the lower its internal resistance the better. Long life on open or closed circuit is also a desirable feature, for replacements are both expensive and annoying. But what is far worse than a gradual deterioration, which is seen and can be calculated for, is a sudden going to pieces of the cell, which may leave a man helpless in the midst of pressing work. This is a serious fault of the silver chloride battery, for they often generate a gas which sooner or later causes them very unexpectedly to explode.

I desire to bring to your notice to-night some new dry cells, one type of which is designed for testing use and another for running induction coils. They are the final result arrived at after some months spent in experiments at the electrical laboratory of Queen & Co.

The points brought out in this paper were kept well in mind in the construction of these cells and after many changes in the details the following forms of cells were finally settled upon:

The "Test" Cell.—As portability is a great desideratum with test cells and as only a very small current is taken from them, the cell designed for this purpose was reduced in size very much from those usually used. They are made in what are called round bottom specimen tubes. The smallest size constructed have a length of two inches with an outside diameter of only half an inch (see *Fig. 1*). In spite of this small size the average resistance of these cells when first made up is not greater than twenty-five or thirty ohms, and after the cell has been put in use the resistance grad-

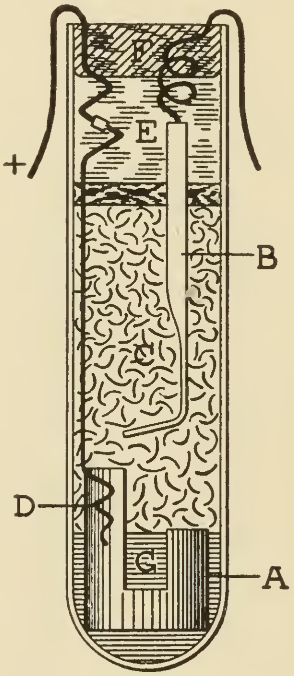

FIG. 1.—Small iodine test cell, 2 inches long by ½ inch in diameter.

A = carbon electrode.
B = zinc electrode.
C = paste made of $AlCl_3 + ZnO + MnO_2 + H_2O$.
D = fine platinum wire moulded into carbon electrode.
E = viscous seal.
F = plaster Paris seal.
G = depolarizer, which may be I_2S_2 giving 1·35 volts, or $HgO + I$ giving 1·65 volts initially with an average of 1·4 volts.

ually falls a few ohms. The electro-motive force of this cell when the depolarizer is sulphur iodide (I_2S_2) is 1·45 volts. They will thus average 1·4 volts. The silver chloride cell with a case of paper and paraffine upon it, which is required to keep the glass from flying when they explode, measures $2\frac{3}{4}$ inches in length by $\frac{7}{8}$ of an inch in diameter; being round they thus have a total volume of 1·62 cubic inches. One of the cells here described, which I may call the iodine cell, iodine being the active depolarizer, has but four cubic inches or less than one-fourth the volume of the silver chloride cell; or 100 silver chloride cells would require seventy-six square inches of space against twenty-five required by an iodine cell. Further, as the electro-motive force of an iodine cell is about 1·4 as against ·9 of a volt for a silver chloride, we have

$$\frac{1}{3} \times \frac{\cdot 9}{1 \cdot 4} = \frac{3}{14}$$

or practically one-fifth the space is required to obtain a given electro-motive force as is needed if silver chloride cells are used. If this decrease in size is at the expense of a corresponding decrease in efficiency, it might not be advisable, but such is not the case, for these cells will give, with such external resistances as are ordinarily used in test work, fully as much current as a silver chloride cell. Further, the total output of these cells is about ·2 to ·3 of an ampère hour. That of a silver chloride is ·6 to ·7; thus while the output of an iodine cell is one-third that of a silver chloride, the volume is only one-fourth as great. Carbon and zinc electrodes are employed, and the low resistance of these cells is largely due to a peculiar shape given to the carbon electrode (see *A*, *Fig. 1*). The depolarizer consists of I_2S_2, sulphur iodide, which is the only binary compound of iodine insoluble in water, with the exception of a mercury and silver salt, neither of which give a high electro-motive force. This depolarizer is put both below and above the carbon electrode, being filled in as high as the top of the lower prong of the carbon electrode (see *Fig. 1*). Now by the action of the cell a very little zinc iodide is formed, which renders the iodine in the depolarizer slightly soluble. The prongs of the carbon, which is of a fairly porous quality, act like a wick to soak up this soluble portion and thus the electrode is kept perfectly depolarized at the exposed ends. The depolarizer, which is ground into a powder, has, moreover, a little of the paste, which is used in the cell, mixed with it, and thus a fair degree of conductivity is given to the whole mass. These two facts together cause the cell to have a very low internal resistance. Three parts by weight of iodine are used and one part of sulphur, and, as the iodine is very loosely held by the sulphur, we can say that the iodine is practically used in a free state. These cells have also been made using a depolarizer which consists of a chemical compound of HgO, mercury oxide, and iodine, with a slight excess of iodine. The formula of this compound is thought to be Hg_2O, IO_4, HgO, IO_4. This depolarizer gives an initial electro-motive force of 1·65 volts, which, however, falls in time to about 1·4 volts, where it remains nearly constant until the cell is used up. This form of depolarizer is also quite insoluble in the electrolyte used and seems to have a lower resistance when combined with a little of the paste used in the cell than the sulphur iodide. This compound does not become reduced to the metal until the cell is nearly exhausted, so there is no local action which takes place, as might be expected, between reduced globules of mercury and the carbon electrode. Tests are now being made to decide between the relative advantages of these two depolarizers. Queen & Co. have been using both types of cells for some months in adjusting all their resistance coils, and enough has already been learned, through a practical and hard test about each, to make it quite certain that they are both excellently adapted to the use to which they are put.

The paste in these cells consists of zinc oxide and aluminum chloride and water. This combination, by the formation of some aluminum hydroxide and zinc chloride, makes a smooth gelatinous paste of any desired consistency and has the important property of neutralizing the hydriodic acid that is formed in the cell, so that these batteries are quite free from gassing and will never explode. The products of the cell, when the circuit is closed, simply change form until the cell is used up. The following equations express the normal actions that probably take place:

$$\text{(I) } Zn_x + 2\,AlCl_3 + 6\,H_2O + 3\,ZnO + [X\,(ZnCl_2)] + [X\,(Al\,(OH)_3)] + 3\,I_2S_2 + C = Zn_{x-z} + 3\,ZnCl_2 + 2\,Al\,(OH)_3 + 6\,HI + 3\,ZnO + [X\,(ZnCl_2)] + [X\,(Al\,(OH)_3)] + 3\,S_2 + C.$$

$$\text{(II) } 6\,HI + 3\,ZnO = 3\,H_2O + 3\,ZnI_2.$$

Some zinc chloride may also take part in the action when the cell is first started and later some zinc iodide. Some of the HI is also probably neutralized thus:

$$Al\,(OH)_3 + 3\,HI = AlI_3 + 3\,H_2O.$$

$AlCl_3$ is used in preference to salts of the alkali metals, for it has no dissolving action whatever on either of the depolarizers above described, which many other salts dissolve to a greater or less extent. Powdered charcoal, or preferably manganese dioxide, is also added to the paste, partly to thicken it and chiefly to improve the appearance of the cell. The fact that the zinc iodide, formed after the cell has been in action, dissolves the depolarizer to a certain extent, may be thought to be a disadvantage, but it is rather an advantage, for while it reduces the resistance of the cell, it also makes the depolarizer much more efficient in its action than it would be if absolutely insoluble. In fact, if a depolarizer is perfectly insoluble, its action must be tardy, and a cell using such will not only soon polarize, but usually have a very high resistance.

The seal in these cells is made as follows (see *Fig. 1*): The zinc electrode is held in place by a cork, over this is poured a hot mixture of gutta-percha, pitch and resin oil. This viscous material is then made secure by having poured over it a layer of the same mixture with an equal part of plaster Paris mixed through it. The terminals are both brought out of the top of the cell (see *Fig. 1*), one being of platinoid and the other of copper wire, so that the poles may be distinguished from each other.

[*To be continued.*]

BOOKS RECEIVED.

[In sending books for notice in the *Journal*, publishers are requested, for the information of the reader, as well as for their own advantage, to give the price. This announcement by title will be followed, in most cases, by a review, which will appear at the earliest opportunity.]

Infantry Drill Regulations, United States Army. Adopted October 3, 1891. New York: Army and Navy Journal and D. Appleton & Co. 1893. Price, 50 cents.

Annual Report of the Chief of the Bureau of Steam Engineering for the Year 1892. Navy Department. Washington: Government Print. 1892.

First Report of the Bureau of Mines, 1891. Printed by order of the Legislative Assembly of Ontario. Toronto: Government Print. 1892.

Leland Stanford University Publications—Studies in Electricity No. 1. Some Observations on the Conductivity of a Copper Wire in Various Dielectrics. By Fernando Sanford, M.S., Palo Alto, Cal. University Press. 1892. Price, 50 cents.

Department of the Interior. United States Geological Survey. J. W. Powell, Director. Coal. By E. W. Parker. Washington: Government Print. 1892.

Public Ledger Almanac, 1893. George W. Childs, publisher. Philadelphia.

A Memorial to Congress with Subject of a Road Department at Washington, and a Comprehensive Exhibit of Roads, their Construction and Maintenance at the World's Columbian Exposition. Boston. Albert A. Pope.

First Annual Report of the Enterprise Mining Company, September 30, 1892, with a Description of the Property. By Leo Von Rosenberg. Maps and Illustrations. New York. 1892.

Magnetic Observations at and near Albany, N. Y., between the Years 1686 and 1892. By Verplanck Colvin.

Foster Engineering Company, Newark, N. J. Catalogue.

Joseph Dixon Manufacturing Company, Newark, N. J. Catalogue.

Annuaire pour l'an 1893, publié par le Bureau des Longitudes, avec des Notices Scientifiques. Paris: Gauthier-Villars et fils. 1893. Prix, 1.50 fr.

BOOK NOTICES.

Encyclopédie Scientifique des Aides-Mémoire. Publiée sous la direction de M. H. Léauté, Membre de l'Institut. Gauthier-Villars et fils et G. Masson. (*Section de l'Ingénieur.*)

Les Textiles Vegétaux; leur examen micro-chimique, par H. Lecompte. Broché 2 francs 50 c. Cartonné 3 francs.

L'Art de Chiffer et de déchiffer les dépeches secrètes, par M. le Marquis de Vairis. Br. 2.50 francs ; Cart. 3 francs.

Cordierie. Cordages en chandre et en fils metalliques, par M. Alheilig. Br. 2.50 francs ; Cart. 3 francs.

La Formation des Gites Metalliféres, par L de Launay. Br. 2.50 francs ; Cart. 3 francs.

Essais d'Or et d'Argent, par H. Gautier. Br. 2.50 francs ; Cart. 3 francs.

Les Acariens parasites, par P. Méquin. Br. 2.50 francs ; Cart. 3 francs.

Canon, Torpilles et Cuirasse : leur installation a bord des batiments de combat, par A. Croneau. Br. 2.50 francs ; Cart. 3 francs.

État actuel de la Marine de Guerre, par L. E. Bertin. Br. 2.50 francs ; Cart. 3 francs.

Analyse des Vins, par le Dr. Magnier de la Source. Br. 2.50 francs ; Cart. 3 francs.

Since our recent notice of this extremely useful series of publications now being issued from the press of Gauthier-Villars & Masson, the volumes above entitled have appeared. Each of them forms an independent volume, though forming part of a comprehensive enclopædic publication covering the entire domain of the sciences as applied to the useful arts. Each volume comprises about 200 pages of octavo size, and wherever the subject admits of it, there are illustrations. This plan of the series is admirable and each volume gives a lucid account of the present state of the art to which it relates.

W.

Logarithmic Tables. By Prof. George William Jones, of Cornell University. Fourth Edition. London : MacMillan & Co. Ithaca, N. Y.: Geo. W. Jones. 1893. $1.

With this new edition Professor Jones' well-known and favorably-known tables appear in a form entirely new, and in most, or in all respects, greatly improved.

The most striking innovation is the material increase in the size of the pages without corresponding enlargement of the type used.

At the same time the very important improvement has been made of placing only fifty lines on a page in the tables of logarithms, instead of sixty, as heretofore, thus bringing each hundred of numbers upon two facing pages.

These changes give, of course, a much more open page, and will, we think, render the use of the tables even less trying to the eyes than before.

We fail to see the advantage of the abandonment of the use of bold-face type in the head-lines and foot-lines and in the side columns.

The volume has grown from 96 to 120 pages. Among the more important additions are tables of four-place logarithms, of four-place trigonometric functions, of prime and composite numbers, of roots and of powers and of reciprocals. Several of the old tables now appear in greatly extended form.

As a guarantee of correctness, notwithstanding the resetting of the entire work which this edition involves, the author-publisher continues his offer of $1 for the first notice of any error.

The tables are a model of typographical excellence, and the profits at the very low price named must be near the vanishing point. T.

Manual of Qualitative Blow-pipe Analysis, and Determinative Mineralogy. By F. M. Endlich, Ph.D. New York: The Scientific Publishing Company. 1892.

The author of this work was a pupil of Richter. He has evidently given this particular branch of qualitative analysis much study, and writes as one who is in love with his work. As a result his book is comprehensive and thorough. It contains all of the most recently discovered reactions that are of value, and gives considerable space to the behavior before the blow-pipe of the rarer elements. The determinative tables are very complete, occupying over 130 pages, about one-third of the entire book.

The book needs an index to minerals, since without it, the student, in using the tables, is obliged to use the deductive method exclusively.

On the front of p. 308, a method of detecting potash in muscovite is given that will show potash whether it be present or not. P.

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, March 15, 1893.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, March 15, 1893

MR. H. R. HEYL, Chairman *pro tem.*

Present, eighty-nine members and six visitors.

Additions to membership since last report, eleven.

The Secretary reported the resignation of Messrs. Philip Pistor and W. M. McAllister from the Committee on Science and the Arts.

On motion, it was decided to fill the vacancies at the next stated meeting.

Mr. James M. Price read a paper on "The Price Metallic Ties," illustrating the subject by the exhibition of diagrams and specimens.

Mr. Alex. E. Outerbridge, Jr., read a paper on "The Modern Traveling Crane," illustrated by several lantern views. Referred for publication.

On account of the lateness of the hour, it was decided to postpone until the next stated meeting the communication of Mr. John M. Hartman, on "Ancient Egyptian Architecture."

For the same reason, the Secretary's report was deferred.

Adjourned. WM. H. WAHL, *Secretary.*

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DUTY TRIAL OF A PUMPING ENGINE, BUILT BY THE GEO. F. BLAKE MANUFACTURING COMPANY.

By F. W. DEAN, S.B.

Late in 1889, the city of Newton, decided to add to their pumping plant a new engine and two new boilers, and the writer was engaged as consulting engineer. He advised the Water Board to accept the bid of The Geo. F. Blake Manufacturing Company, not only because the price was the lowest, but because it was evident that their offer was for the highest type of compound engine. It was true that no engine like this had been built, but he had sufficient confidence in the builders to believe that they would succeed in designing a durable and highly efficient engine. The result proved the wisdom of the choice, for after some mishaps and experimentation incident to a first machine, the pumping engine emerged a very economical and successful piece of mechanism.

There is little to be said beyond that contained in the report of the official test of the Water Board, except as to the reasons why the engine gave a higher duty on this test than on that conducted by Professor Peabody. This was due chiefly to changing the supply of the live steam entering the re-heater, and doubtless to the valves having had time to wear to more accurate fits. The re-heater live steam originally came by an independent small pipe of considerable length from the bottom of the steam drum, thus conveying all condensation that had accumulated as far as the bottom of the drum, and all that formed in the small pipe to the re-heater. Before making the official test the re-heater live steam was taken from the main steam pipe as near the engine as possible, and this arrangement became permanent. Moreover, as five months had elapsed between the two tests it is evident that everything was in the better order at the later date.

Concerning the lower efficiency of the mechanism during the second test, the reason was doubtless due to air entering the suction pipe, coupled with the greater speed of the pump. At times sufficient air would enter to make very loud knocks. It was caused by the lowness of the water in the well, and this could not be raised. When the air entered the pump, indicator cards showed great fluctuations in pressure, but when there was water enough in the well the pump diagrams were as smooth as those shown in Professor Peabody's report. The harmful condition existed so much of the time that there was without doubt much energy wasted in the pump end.

The boiler performance was better on the second test, although better coal was used on the first test. This was due to experience gained in firing during the interval of five months.

* * * The contract required an engine capable of pumping 5,000,000 gallons in twenty-four hours, with a guaranteed duty of 115,000,000 foot-pounds of work by the consumption of a quantity of water evaporated into dry

steam, the equivalent of which is 1,100 pounds of water evaporated from and at 212° F. The method of computing this duty is fully explained in the specifications and is as follows: "The area of the plunger(s) in square feet will be multiplied by the pressure in pounds due to the total lift in feet, which will be obtained from the average reading of a correct pressure-gauge attached to the force main near its connection to the pump, to which will be added the pressure due to the difference of level between the zero of the gauge and the water in the pump well, the product thus obtained will be multiplied by the total number of feet traveled by the plungers on their discharging strokes. This product equals the total work in foot-pounds. The amount of water evaporated by the boilers during the trial will be reduced to an equivalent number of pounds of water evaporated from and at 212° F. The total work in foot-pounds divided by this equivalent evaporation and the quotient multiplied by 1,100 will be the duty of the engine in foot-pounds per specified unit of water evaporated into steam."

Soon after the contract was made the American Society of Mechanical Engineers advocated, through a committee instructed to devise a standard method of conducting duty trials of pumping engines, the computation of duty upon the consumption by the engine of 1,000,000 units of heat. In consequence of this, the duty has been computed upon this basis as well as upon the other.

The contract also embraces the installation of two boilers of the locomotive type having the Belpaire system of staying the crown sheets. Each boiler was to be sufficiently large to easily furnish steam for the engine to full power. Through the liberality of the contractors, The Geo. F. Blake Manufacturing Company, these boilers were designed to safely carry 150 pounds by gauge to the square inch, although the usual working pressure was to be less than 130 pounds. These boilers were guaranteed to evaporate no less than eleven pounds of water per pound of combustible reduced to the equivalent of feed-water at 212° and evaporation at that temperature.

The engine is a new type of cross compound fly-wheel horizontal pumping engine with the Corliss type of valve gear, designed and built by the contractors, The Geo. F. Blake Manufacturing Company. It consists of one high-pressure cylinder and one low-pressure cylinder side by side and two double-acting horizontal pumps similarly arranged. Each pump has its axis coincident with that of one steam cylinder, and the companion steam piston and pump rods are both keyed to a cross-head about midway between the steam and pump ends of the engine, there being therefore two cross-heads. These cross-heads slide upon guides which form tie rods between the steam cylinders and pumps.

Near each steam cylinder there is a vertical beam working on horizontal bearings formed in a lower bed plate. These beams are operated by links passing from journals on the cross-heads to pins in the upper ends of the beams, and motion is transmitted to the fly-wheel shaft by means of connecting rods passing from pins near the middle of the beams to the pins of cranks on the ends of the shaft. The shaft rotates in boxes formed in the bed plate before mentioned. The cranks are at right angles to each other, the low-pressure crank leading.

The valve gear possesses novel features. Among them may be mentioned the absence of springs from the latching mechanism, and the operation of this mechanism by a special eccentric for each cylinder. There is a high speed centrifugal governor which varies the cut-off through a wide range. The inlet and exhaust valves of the low-pressure cylinder are driven by different eccentrics.

The cylinders are jacketed by steam on its way to the steam chests, and between the cylinders there is a tubular re-heater, the re-heating being done by live steam taken from the main steam pipe near the engine.

There is a coil feed-water heater in the exhaust pipe of the low-pressure cylinder, and the main feed pump forces the water through this coil to the boiler. Another pump forces the water formed by the condensation of the live steam in the re-heater to the boiler. The condensation in the main steam pipe, that in each jacket, and that in the exhaust steam side of the re-heater, are trapped and wasted.

The air pump is vertical and single-acting, and it and both feed pumps are operated from arms on an extension of the low-pressure beam axis pin.

The main pumps are, as before stated, double-acting and are provided with a large valve area.

PRELIMINARY TEST.

A preliminary test of three hours' duration was made a few days before the official test, as prescribed in the American Society Code, in order to establish working temperatures, the conditions of working being substantially the same as during the official test. These temperatures were properly modified to suit the slightly changed conditions during the test. The modifications consisted in reducing the average temperature of the re-heater drain supply at the boiler 1°·11, and reducing that of the main feed at the boiler 4°·6. The higher temperature of the main feed might have been used in computing the results of the official test, had it not been for the fact that the contractor preferred to run this test with a vacuum one inch greater than during the preliminary test. The hot well temperature was thus reduced some 6°. Under these circumstances it was thought an unjustifiable assumption to suppose that the total heat effect of the steam during the official trial would be correctly represented, considering the different vacuums in the two trials, by using the main feed temperature as determined during the preliminary trial. This is in the direction of conservatism, and is one reason for supposing that the engine can give even higher duties than those here tabulated. During the official test the main feed was taken from the pump well and the average temperature was 59°·47. This water passed through the feed-water heater and left the engine only 3°·81 lower than during the preliminary test, and entered the boiler as before stated only 4°·6 lower.

THE OFFICIAL TRIAL.

The fires in No. 2 boiler, which had been thoroughly cleaned, were lighted some four hours before the trial was to begin. The engine was run also for about an hour before the trial, thus heating both boiler and engine to their normal working temperatures. The engine was stopped and the fires were drawn. New fires were immediately started and the pressure of steam and height of the water accurately taken. As soon as practicable, the engine was started and the boiler test was considered as begun, the time being 9.42 A.M., September 30, 1892.

The feed-water weighing also began, the re-heater drain was running to waste, and each man was at his post. At precisely 10 A.M. the feed-water level in the lower tank, and the water level in the boiler were accurately noted and the re-heater drain turning into a hogshead of cold water placed upon scales. Previous to beginning the boiler test all pipes in both boiler and engine rooms which could convey either water or steam to or from any point so as to vitiate the accuracy of the results, were disconnected, and it was ascertained that no valves leaked. In connection with this it may be stated that all pressures were taken with nice test gauges which were known to be correct, all temperatures with high-grade tested thermometers and all indicators were provided with tested springs. All scales used for weighing coal and water were made correct with standard weights.

The pressure of the water in the force main was taken every ten minutes and the distance below the point at which this pressure existed was measured by an adjusted scale resting upon a float upon the water in the pump well. It was read simultaneously with the pressure-gauge. The scale also showed the total suction lift of the pump, and this was read every ten minutes. The total pressure against which the pump acted was computed from the gauge and float readings and the weight of water corrected for its temperature.

On account of the scarcity of water in the pump well the suction lift was excessive and did not permit the pumps to work advantageously. The friction of the pump was much more than in a previous test carried out by Prof. C. H. Peabody. A portion of the extra friction was doubtless caused by the greater speed of the engine in this test. The average number of revolutions per minute in Professor Peabody's test was 37·695, and in the official test 39·115.

Indicator diagrams were taken from the steam cylinders every twenty minutes, two Crosby indicators being used on the high-pressure cylinder and two Thompson indicators on the low-pressure cylinder. Indicator diagrams were occasionally taken from the pumps with Thompson indicators.

Pressures were taken every twenty minutes at the boiler, at the throttle, and on the steam supply end of the re-heater. The counter was read every twenty minutes. Temperatures were taken, every twenty minutes, of the feed-water before passing the heater; immediately after passing the heater; of the re-heater drain immediately after leaving the re-heater, and about four feet beyond; of the feed-water where it entered the boiler; and of the flue temperatures during the first nine hours and last two hours of the test. Only one reading was taken at the hot-well.

No calorimetric observation of the quality of the steam were taken, as this was done by Professor Peabody a few months before his results being accepted as applicable to this test. The calorimeter was applied near the throttle, and the moisture was found to be seven-tenths of one per cent. This was held to be due to condensation in the steam drum and steam pipes, which were rather long. The boiler was supposed to furnish dry steam.

As the time approached for ending the test the fire was burned down as low as practicable while keeping the pressure nearly constant, and the water in the boiler at its normal height. At the end of twenty-four hours the height of the feed-water in the lower barrel was marked, the water in the boiler being at the original height, and the jacket drain turned to waste. The engine test was then completed. The engine was immediately stopped, the water brought to the original boiler test level, with the original pressure and the boiler test ended. The fire was then drawn and the unconsumed coke picked out and deducted from the coal fed into the fire boxes. The level of the feed-water in the lower tank was noted at the end of the boiler test.

After the test was over the quantities of water necessary to bring the water in the lower feed tank to the original engine test and boiler test levels were weighed.

It is obvious that the engine test was shorter than that of the boiler, and the coal quantity to be credited to the engine was ascertained by making it proportional to the number of heat units which passed to the engine from the boiler during the engine test.

In the table which follows it will be seen that the amount of steam used per hour per indicated horse-power is given with the moisture deducted in order to compare this result with similar results from other engines. While it is not strictly proper to make this deduction, the result is probably more nearly correct than if the deduction were not made. It is true that the heat in the moisture passes through the engine and may do good somewhere, but considering the fact that the moisture is known to do harm, and that the engine is not responsible for it, the benefit from the heat is doubtful. Little or none of it can flash into steam during its course because heat of vaporization is so much greater than heat of liquid. This discussion seems necessary in view of the fact that the steam consumptions given, place this engine among the most economical in the world.

The following tables give the principal dimensions of the engine and boilers with the results of the trial in detail:

Dimensions of the Engine.

(1) Type, cross compound, fly-wheel	
(2) Diameter of high-pressure cylinder, . . .	21 inches.
(3) Diameter of low-pressure cylinder, . . .	42 inches.
(4) Diameter of each pump plunger, ...	13½ inches.
(5) Diameter of piston and plunger rods, . .	4 inches.
(6) Stroke of all pistons and plungers, . . .	40 inches.
(7) Diameter of one single-acting air pump, .	26 inches.
(8) Stroke of same, ...	12 inches.
(9) Diameter of single-acting plunger feed pump, ...	4½ inches.
(10) Stroke of same, ...	6 inches.
(11) Diameter of pump plunger for returning re-heater drain to boiler, ...	2 inches.

(12) Stroke of same,	6 inches.
(13) Ratio of volume of low-pressure cylinder to high-pressure cylinder,	4 to 1
(14) Volume of pump cylinder corresponding to one displacement of plunger average,	3·167 cubic feet.
(15) Diameter of suction main,	24 inches.
(16) Diameter of force main at engine house,	24 inches.

Dimensions of the Boiler.

(17) Smallest inside diameter of shell,	84 inches.
(18) Inside length of fire box,	8 feet.
(19) Inside width of fire box (twice 3 feet 5¼ inches),	6 feet 10½ inches.
(20) Length of combustion chamber,	4 feet.
(21) Length of tubes,	16 feet.
(22) Diameter of tubes, outside,	3 inches.
(23) Number of tubes,	170
(24) Length of grate,	7 feet.
(25) Width of grate (twice 3 feet 5¼ inches),	6 feet 10½ inches.
(26) Heating surface,	2,310 square feet.
(27) Grate surface,	48·125 feet.
(28) Ratio of grate to heating surface,	48·00

Engine Test.

(29) Duration of trial,	24 hours.

Average Pressure, etc.

(30) Steam pressure at the boiler by gauge,	125·60 pounds.
(31) Steam pressure at the throttle valve by gauge,	122·31 pounds.
(32) Pressure of atmosphere by barometer,	14·72 pounds.
(33) Absolute steam pressure at boiler,	140·32 pounds.
(34) Absolute steam pressure at throttle valve,	137·03 pounds.
(35) Vacuum by gauge,	27 inches.
(36) Weight of one cubic foot of water at 59°·5 F.,	62·37 pounds.
(37) Water pressure in gauge chamber,	96·83 pounds.
(38) Difference in level of gauge and water in pump well,	21·14 feet.
(39) Corresponding pressure,	9·156 pounds.
(40) Total water pressure (head),	105,986 pounds.
(41) Minimum suction lift,	21·84 feet.
(42) Maximum suction lift,	23·23 feet.

Average Temperatures.

(43) Of engine room,	75°·96 F.
(44) Of external air,	60°·50 F.

(45) Of feed-water at boiler, as deduced from preliminary test,	129°·90 F.
(46) Of re-heater drain at re-heater,	341°·40 F.
(47) Of re-heater drain at boiler as deduced from preliminary test,	280°·30 F.
(48) Of water in pump well,	59°·50 F.

Feed Water.

(49) Total water pumped into boiler during engine test,	84,491 pounds.
(50) Moisture in steam at throttle,	0·007
(51) Steam used in cylinders of engine,	79437·12 pounds.
(52) Steam used in re-heater,	5053·88 pounds.
(53) Steam used per hour per indicated horse-power, excluding moisture,	13·97 pounds.
(54) Steam used per hour per indicated horse-power, including moisture,	14·07 pounds.

British Thermal Units.

(55) Per pound of steam used in the cylinders,	1093·05
(56) Per pound of steam used in the re-heater,	870·55
(57) Total used in the cylinders and re-heaters,	91,228,399
(58) Total used in the cylinders and re-heater in twenty-four hours,	91,228,399
(59) Supplied by boiler per pound of steam from 129°·9 F. to 140·32 pounds absolute,	1091·56
(60) Total supplied by boiler in twenty-four hours,	92,215,632
(61) Total supplied per pound of coal,	10816·8
(62) Total supplied per minute per indicated horse-power,	253·14
(63) Efficiency of the engine,	16·9 per cent.

Average Powers Developed.

(64) Total number of revolutions in twenty-four hours,	56,326
(65) Average number of revolutions per minute,	39·115
(66) Average mean effective pressure in high-pressure cylinder,	42·44 pounds.
(67) Average mean effective pressure in low-pressure cylinder,	12·50 pounds.
(68) Horse-power developed by high-pressure cylinder,	114·3
(69) Horse-power developed by low-pressure cylinder,	136·24
(70) Horse-power developed by both cylinders,	250·27
(71) Percentage of total power developed in high-pressure cylinder,	45·6 per cent.

(72) Percentage of total power developed low-pressure cylinder, ...	54·4 per cent.
(73) Horse-power of water plungers, ...	229·23
(74) Efficiency of mechanism, ...	91·6 per cent.
(75) Steam accounted for by indicator at cut-off high-pressure cylinder, ...	8·78 pounds.
(76) Steam accounted for by indicator at release, high-pressure cylinder, ...	10·35 pounds.
(77) Steam accounted for by indicator at cut-off low-pressure cylinder, ...	9·20 pounds.
(78) Steam accounted for by indicator at release, low-pressure cylinder, ...	11·41 pounds.
(79) Proportion of above to feed-water consumption, at cut-off high-pressure cylinder, ...	63 per cent.
(80) Proportion of above to feed-water consumption, at release high-pressure cylinder, ...	74 per cent.
(81) Proportion of above to feed-water consumption at cut-off low-pressure cylinder, ...	66 per cent.
(82) Proportion of above to feed-water consumption, at release low-pressure cylinder, ...	82 per cent.
(83) Percentage of total steam, used by cylinders, ...	94·02 per cent.
(84) Percentage of total steam used by reheater, ...	5·98 per cent.

Boiler Test.

(85) Duration, ...	24·38 hours.

Average Pressures.

(86) Steam pressure at boiler by gauge, . . .	125·60 pounds.
(87) Atmospheric pressure by barometer, . . .	14·72 pounds.
(88) Absolute steam pressure, ...	140·32 pounds.
(89) Force of draught, inches of water, ...	·35 inches.

Average Temperatures.

(90) Of external air, ...	60°·5 F.
(91) Of fire room, ...	81°·5 F.
(92) Of escaping gases during the first nine hours, ...	391° F.
(93) Of escaping gases during the last two hours, ...	494° F.

[NOTE.—The results (75) to (82), both inclusive, are necessarily approximate for the whole test, and indicate steam behavior in a general way only.

(94)	Of feed-water before entering heater, . .	59°·5 F.
(95)	Of feed-water before entering boiler, . . .	129°·9 F.

Fuel.

(96)	Total weight of dry coal consumed, including equivalent of wood, ...	8653·6 pounds.
(97)	Total dry refuse, weight, ...	632·6 pounds.
(98)	Total dry refuse, percentage, ...	7·3 per cent.
(99)	Total combustible weight, ...	8,022 pounds.
(100)	Total combustible percentage, ...	92·7 per cent.
(101)	Total calorific value of one pound of coal by experiment, ...	13,452 B.T.U.
(102)	Total calorific value of one pound of coal by analysis, ...	14,373 B.T.U.

Calorimetric Test of Steam.

(103)	Percentage of moisture in steam, ...	$\frac{7}{10}$ of 1 per cent.

Water.

(104)	Total weight of water pumped into boiler and apparently evaporated, ...	85,011 pounds.
(105)	Equivalent water evaporated from and at 212° F., ...	96,912 pounds.
(106)	Equivalent total heat derived from fuel in British thermal units, ...	93,602,212
(107)	Equivalent water evaporated from and at 212° per hour, ...	3,975 pounds.

Economic Performance.

(108)	Water evaporated per pound of dry fuel from average temperature of feed (129°·9) at average steam pressure (125·6 pounds),	9·91 pounds.
(109)	Equivalent water evaporated from and at 212°, ...	11·19 pounds.
(110)	Equivalent water evaporated from and at 212° per pound of combustible, ...	12·08 pounds.
(111)	Equivalent total heat derived from a pound of dry coal, ...	10816·8 B.T.U.
(112)	Dry coal burned per hour per square foot of grate surface, ...	7·38 pounds.
(113)	Water evaporated per hour per square foot of heating surface from and at 212° F.,	1·51 pounds.

Duties.—Based upon the heat given to each pound of water fed to the boiler:

(114)	Per Newton Basis, ...	125,497,323 ft. lbs.
(115)	Per 100 pounds of coal burned, ...	127,779,469 ft. lbs.

Based upon the heat received and rejected by the engine:

(116)	Per 1,000,000 British thermal units, . . .	119,406,777 ft. lbs.

Analysis of coal used.

KIND OF COAL, GEORGES CREEK, CUMBERLAND.

	Per Cent.
Moisture,	·58
Carbon,	79·40
Hydrogen,	5·11
Oxygen,	3·80
Nitrogen,	1·25
Ash,	9·24
Volatile sulphur,	·62

The duty on the Newton Basis is 125,497,323 foot-pounds, or $9\frac{12}{100}$ per cent. above the guaranteed duty of 115,000,000 foot-pounds.

The boiler evaporated 12·08 pounds of water per pound of combustible, from and at 212° F., and therefore exceeded the guarantee of 11 pounds by 10·98 per cent.

Although the specifications require a test of each boiler there appears to be no reason for another test as the boilers are exact duplicates.

The engine runs smoothly at all times and will always be very economical. Whether looked upon from the standpoint of excellence of design, workmanship, durability or stability, the engine is second to no horizontal pumping engine in the country.

The results of the boiler trial show the boiler to be among the most economical on record, and this high degree of economy will be maintained indefinitely.

CAPACITY OF PUMPS.

The amount of water displaced by the pump plungers during the test, no allowance being made for slip, was 5,339,141 gallons in twenty-four hours. This less four per cent. for slip equals 5,123,575 gallons in twenty-four hours. As no weir measurement could be made of the qantity of water pumped the actual slip is not known. No method* of ascertaining slip other than by weir measurement can give a result which is more than an assumption, and as four per cent. is rarely reached, it is safe for the city's interest to use this.

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* A Venturi tube might have been used in the discharge pipe, giving an error of about one per cent. F. W. D.

TEST OF A ONE HUNDRED HORSE-POWER GAS ENGINE USING PRODUCER GAS.

BY H. W. SPANGLER.

About a year ago the makers of the Otto gas engine, Messrs. Schleicher, Schumm & Co., stated that they were then completing a 100 horse-power gas engine, and that their plant was run on producer gas and the engine would be at our service to make a test to determine the amount of coal used per horse-power. Unfortunately this engine was not completed before the end of the college year, so that it was practically impossible to carry out the test at that time. Later in the year another engine of the same size was under way and was offered to us at a time that we could do the work, and we gladly undertook to make as full a test as the means then at hand would allow.

The data were taken by students of the Mechanical Engineering Department of the University of Pennsylvania under my direct supervision, and most of the results were worked out by Messrs Head and Wood for a graduation thesis.

The engine tested was nominally a 100 horse-power, two cylinder Otto gas engine, sections of which are shown in *Figs. 1, 2* and *3*. The cylinders are horizontal, one directly over the other. The general type of the engine is very much that of the ordinary Otto. The connecting rod from the upper piston takes hold of the crank pin, while the connecting rod from the lower piston is attached to the upper connecting rod, some distance back of the pin. The arrangement of the admission and exhaust valves is plainly shown in the figures. The gas and air are admitted through the pipes marked, there being a throttle valve on the gas pipe. The supply valves to the cylinders are disc valves, opening inwardly, and which are held on their seat by a light spiral spring. The exhaust valves are flat valves, which are opened by a cam, as is usual in engines of this type. During the test the relative amounts of air and gas admitted were regulated so that there was as little loss as possible from incomplete combustion.

The engine for testing was set up on the foundation which is usually used at the works for testing large engines before sending them out. The pipe connections for this engine were so made that gas could be used either from the city supply or from the producer, and during the test the joints in the city supply pipe were broken and no gas could get to the mains except such as came from the producer. During the time of the test the engine which runs the factory was disconnected from the pipes carrying the producer gas, and was supplied with gas from the city mains.

A diagrammatic view of the producer is shown in *Fig. 4*.

The producer, which was Taylor's patent, No. 4, consists of a cylindrical shell *D'*, lined with fire brick *E*, at the bottom of which was a grate *F*, which could be turned around its centre by means of gearing *G*, extending outside the base of the producer.

Ashes filled the producer from the grate to about six inches above the top of the air pipe *H*, coming out in the centre of the producer.

The air supply for the producer is derived from the positive blower, driven by shafting in the works. The power necessary to drive it was afterwards determined. The air entered the pipe, at the point marked, from the blower and passed directly into the bottom of the first scrubber up through the wet coke, with which the bottom of the scrubber was filled, then through the air pipe *H* under the coal in the producer. As it passed through the producer it converted the carbon of the coal largely into carbonic oxide, then passed through the pipe *I* into the bottom of the top half of the first scrubber where the pipe dipped into a water seal. After passing up through the first scrubber it passed down, up through the second scrubber and then into the gasholder, the course taken by the air from the point that it entered to the point at which it was discharged into the gasholder, being shown by the arrows.

Coal was fed in through the circular box *J* on the top of the producer, the bottom of which was an inverted cone held up tight by a chain, pulley and weight. The supply of air was regulated by an escape valve *K*, which was closed by the descent of the gasholder.

All the small pipes are water pipes, except the one marked *A*.

The water comes from a tank on the roof, supplying the second scrubber, and continuing to the first, the supply for which is regulated by a float in the small tank *L*. In this manner the scrubbers are cooled and the water seal maintained.

From the small tank *L*, the water flows through the valve *B* into a circular jacket around top of the producer. The valve is governed by the motion of a piston in *C*, which opens *B*, when the temperature of the water in the producer exceeds a fixed height. This was so adjusted that a continuous flow of hot water takes place through the pipe *D* to the top of the lower part of the first scrubber, where it heats and moistens the air before entering the producer, the first scrubber being divided in the middle of its height by an air-tight partition. By this system the steam necessary for the producer is obtained by utilizing the heat which is carried from the bed of fuel by the gas, and by this means the steam boiler usually used in connection with boilers is dispensed with. This method of supplying moisture is the invention of Mr. Paul Winand, of the Otto Works, and a comparison of the following tests with those in which a separate boiler is used for supplying steam shows a decided saving in coal consumed.

During the test the explosion of the gas in the engine was caused by a spark made by the breaking of the circuit of Edison-Lelande cells, a spark coil being in the circuit.

The gas pipe from the producer to the gas bag was eight inches in diameter. The gas bag was a cylinder 3 feet in diameter and 1 foot long, having loose gas-proof ends. A three and one-half inch gas pipe connected the gas bag to the engine.

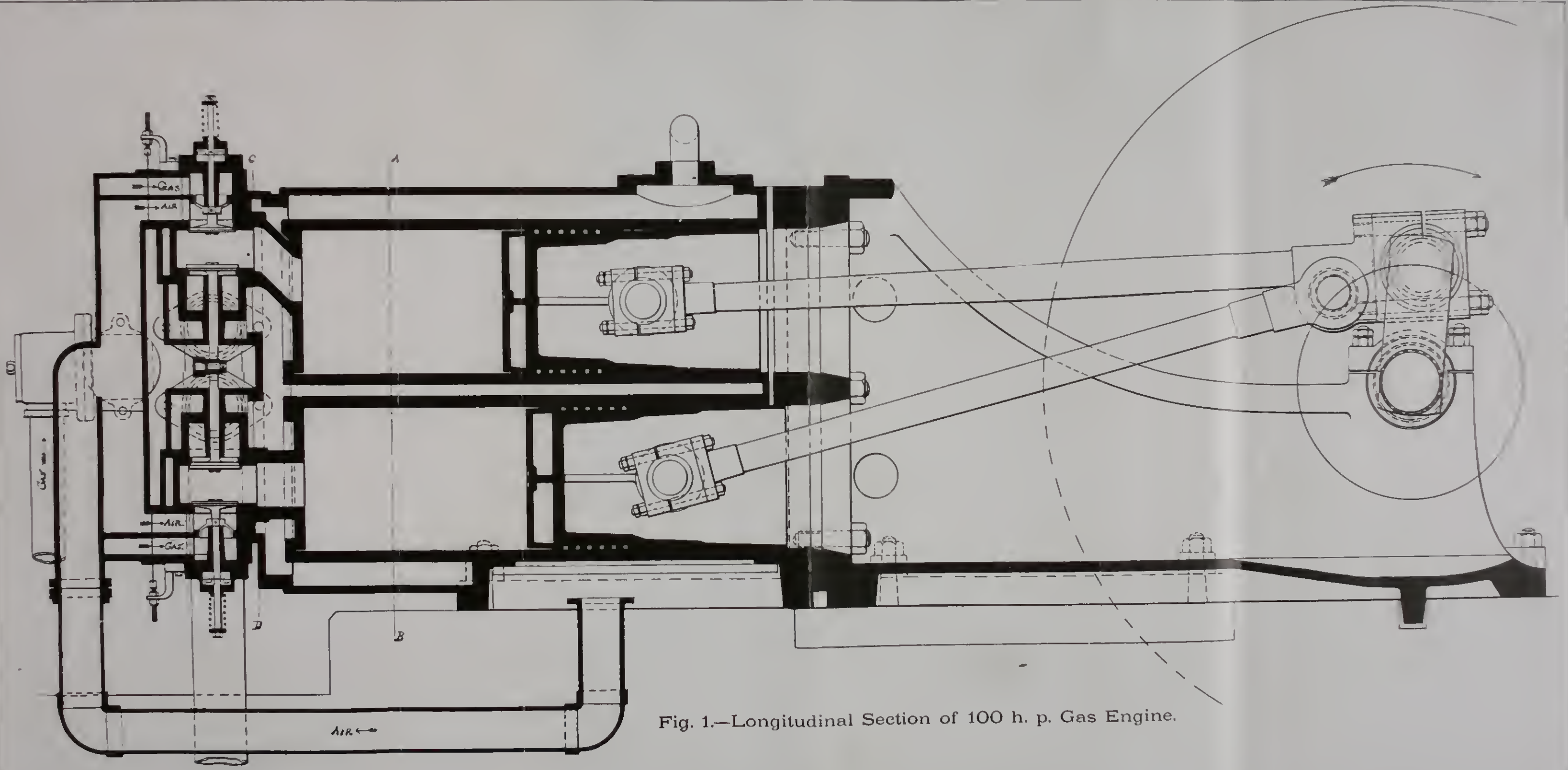

Fig. 1.—Longitudinal Section of 100 h. p. Gas Engine.

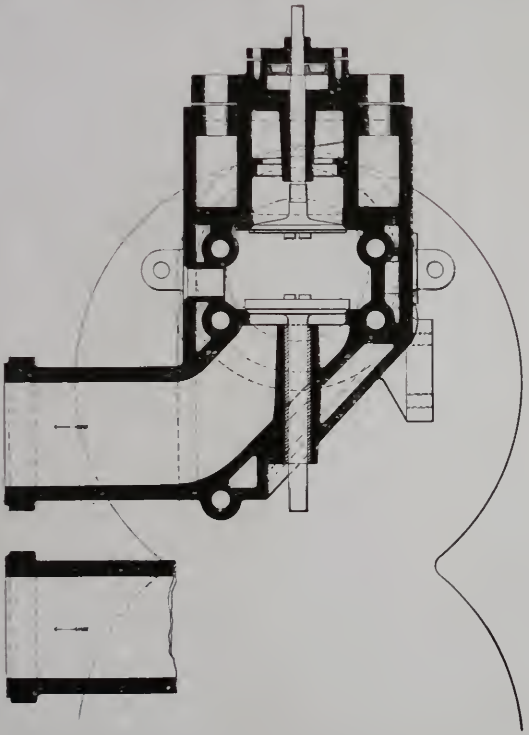

Fig. 3.—Section through Exhaust Valves of 100 h. p. Gas Engine.

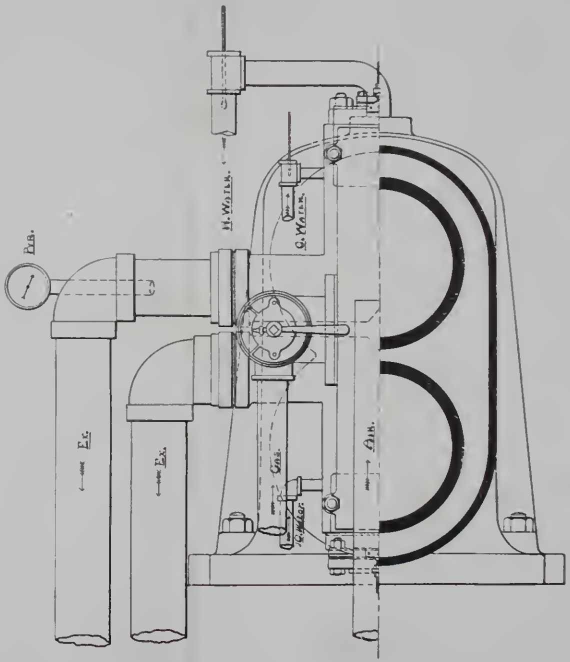

Fig. 2.—Section through Cylinders and End Elevation of 100 h. p. Gas Engine.

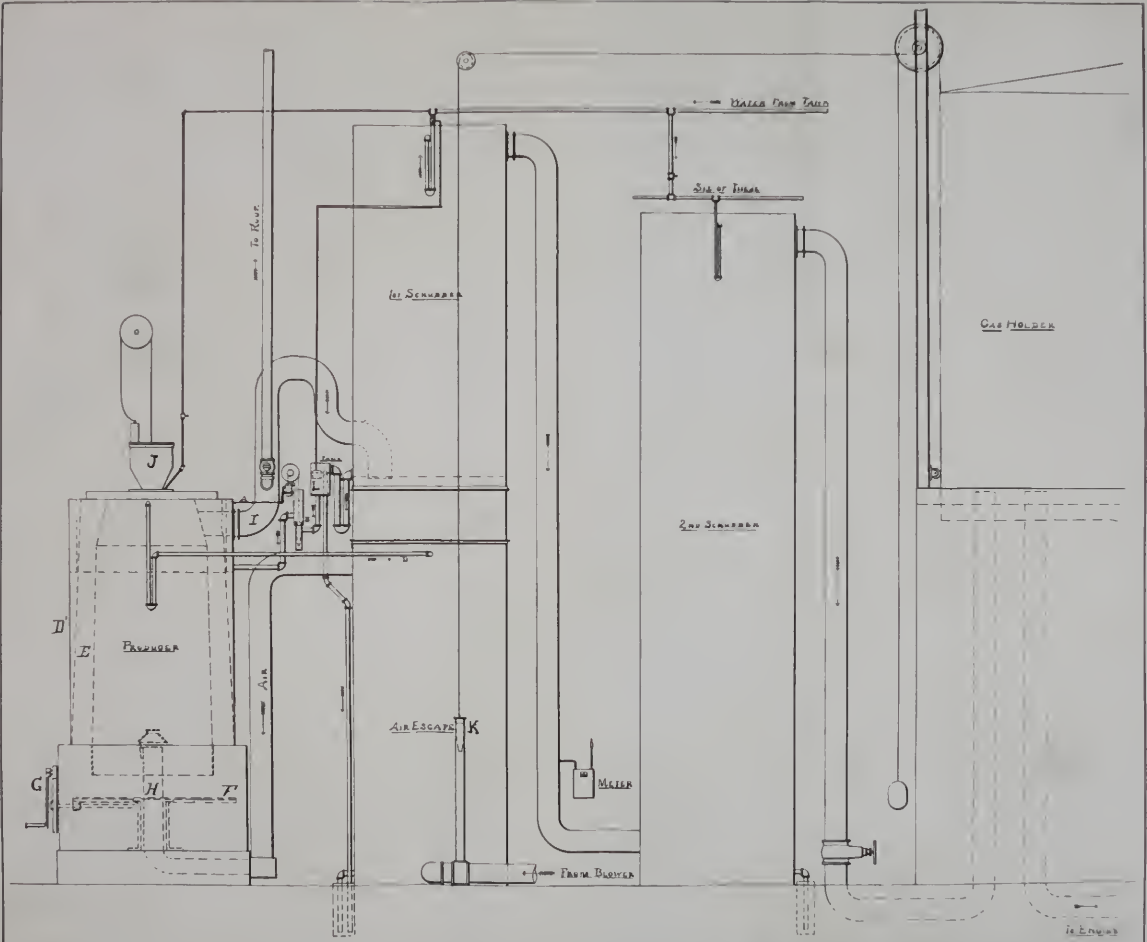

Fig. 4.—Diagrammatic Sketch of Producer Gas Plant.

The method of making the test was as follows:

The coal that was fed to the producer was weighed partly in charges of about 130 pounds, and during a portion of the time the amount used at each firing was noted. Samples of the coal used were taken and afterwards tested under the direction of Prof. Edgar F. Smith, of the University, and was found to have the following composition:

Per Cent.		
4·20	moisture.	
6·88	volatile and combustible,	3·18 per cent. hydrogen. 84·76 per cent. total carbon.
80·41	fixed carbon.	
8·51	ash.	
0·74	sulphur.	

Samples of the gas in the holder were taken at frequent intervals and tests made of it, some of the tests being complete ones, while others simply showed that the conditions remained about constant.

The pressure and temperature of the gas as it went into the gas bag were noted at regular intervals. Indicator cards were taken from both cylinders every half hour during the test. A supplementary wheel was bolted to one of the fly-wheels of the engine, and on this a prony brake was fitted. Water was allowed to run on the inside of the rim of the wheel and evaporate, and as the details of the test will show, no difficulty was experienced in keeping the load reasonably constant.

The temperature of the water used in the jacket was taken throughout the test, and at regular intervals the quantity of water used every four minutes was run into an iron tank and weighed.

A continuous counter was used to record the number of revolutions of the engine, and a counter was fitted in such a way that the number of times the gas valve opened to admit gas was registered.

A Brown's pyrometer was fitted in the exhaust pipe to determine the temperature of the exhaust gas and provision was made by which samples from the exhaust pipe could be taken for each engine and the gas analyzed.

The test proper extended over three days, while preliminary trials were made on the two preceding days. The condition of the fire in the producer was noted on the evening of May 4th, by pushing an iron rod from the top of the producer down to the grate, allowing it to remain long enough to become red hot, then marking the two ends of the hot portion, and measuring the thickness of the bed of ashes and of the bed of coal on the rod. The height of the holder was noted, and the plant shut down until the next morning.

On May 5th, the engine was started at 7.39 A.M. and run continuously until about 5.45 P.M. On May 6th, before starting the engine the producer was started, and the gas allowed to escape into the air, until the producer was making the gas of the proper quality for use in the engine. The engine was started at 7.44 and run until 5.40 at night. On May 7th, the same method of proceeding was taken as on the day before. The engine was started at 7.26 and run until 5.40 in the evening, great care being taken that the amount of fire in the producer at the end of the test—that is at the end of the third day, should be the same as at the beginning of the test, or on the evening of May 4th, and that the holder should be at the same height as at the beginning of the test.

The tables accompanying this paper are the records of the test as made, and *Fig. 5* graphically represents the tables.

Tables 1*a*, 1*b*, and 1*c* show the total reading of the revolution counter, the revolutions per minute, the total reading of the explosion counter, the explosions per minute, the reading of the pyrometer in degrees F., the gas pressure in inches of water, the gas temperature and the room temperature in degrees F., and the load on the brake in pounds. The total time of running the engine was determined from this table in the following way: The total time of running was made up of two parts, one of which commenced when the explosions had become uniform and the load steady, and to this was added the duration given by dividing the number of explosions before and after the time allowed above, by the average number of explosions per minute during this uniform running.

TABLE I (*a*).—May 5th.

Time.	Revolutions Counter.	Revolutions per Minute.	Explosion Counter.	Explosions per Minute.	Pyrometer.	Gas Pressure. Inches.	Gas Temp. F.	Room Temp. F.	Brake Load. Pounds.
7.39	689,190	—	98,773	—	—	—	—	—	—
7.50	690,890	154·	99,905	102·	490·	1⅜	64·6	—	570·
8.00	692,460	157·	101,124	121·9	650·	1¼	64·7	—	820·
8.10	694,020	156·	102,413	128·9	680·	1½	65·2	—	900·
8.20	695,580	156·	103,753	134·	710·	1½	65·8	—	980·
8.30	697,140	156·	105,184	143·1	750·	1½	66·8	—	1140·
8.40	698,690	155·	106,689	150·5	740·	1⅝	67·8	—	1100·
8.50	700,235	154·5	108,166	147·7	745·	1⅝	68·	—	1100·
A.M.									
9.00	701,810	157·5	109,611	149·5	755·	1½	68·2	—	1170·
9.10	703,430	162·	111,222	156·2	770·	1⅝	68·8	—	1150·
9.20	705,047	161·7	112,775	155·3	760·	1⅝	69·2	—	1140·
9.30	706,655	160·8	114,321	154·6	775·	1⅝	70·	—	1155·
9.40	708,290	163·5	115,870	152·9	775·	1⅝	70·3	—	1157·
9.50	709,910	162·	117,413	154·3	780·	1⅝	70·6	—	1160·
10.00	711,530	162·	118,958	154·5	770·	1⅝	71·3	—	1145·
10.10	713,155	162·5	120,492	153·4	755·	1⅝	71·8	—	1145·
10.20	714,775	162·	122,031	153·9	755·	1⅝	71·4	—	1150·
10.30	716,400	162·5	123 566	153·5	760·	1⅝	72·4	—	1160·
10.40	718,020	162·	125,104	153·8	760·	1¾	72·6	—	1160·
10.50	719,640	162·	126,654	155·	755·	1⅝	73·	—	1175·
11.00	721,270	163·	128,161	150·	740·	1¾	74·	—	1125·
11.10	722,890	162·	129,681	152·	745·	1¾	75·4	—	1124·
11.20	724,520	163·	131,211	153·	755·	1⅝	75·7	—	1170·
11.30	726,140	162·	132,773	156·2	755·	1⅝	76·	—	1155·
11.50	729,390	162·	135,815	150·4	750·	1⅝	77·	—	1160·
12 P.M.	731,015	162·5	137,393	157·8	760·	1⅝	77·4	—	1162·
12.10	732,635	162·	138,981	158·8	760·	1⅝	77·6	—	1150·
12.20	734,250	161·5	140,571	159·	760·	1¾	77·4	—	1150·
12.30	735,870	162·	142,141	157·	750·	7¾	77·1	—	1130·
12.40	737,490	162·	143.138	148·7	720·	1¾	78·2	—	1075·
12.50	739,125	163·5	145,122	148·4	730·	1¾	78·8	—	1120·
1.00	740,750	162·5	146,641	151·9	745·	1⅝	78·8	—	1130·
1.10	742,370	162·	148,183	154·2	750·	1¾	79·	—	1130·
1.20	743 985	161·5	149,737	155·4	760·	7⅝	78·3	—	1155·
1.30	745,610	162·5	15,305	156·8	750·	1⅝	79·6	—	1115·
1.40	747,230	162·	153,841	153·6	745·	1¾	80·	—	1100·
1.50	748,860	163·	154,365	152·4	745·	1¾	80·	—	1080·
2.00	750,480	162·	155,881	151·6	745·	1¾	80·2	—	1135·
2.10	752,090	161·	157,451	157·	740·	1¾	79·	—	1095·
2.20	753,710	162·	159,021	157·	740·	1¾	78·8	—	1085·
2.30	755,215	160·5	160,609	157·8	745·	1¾	79·1	—	1120·
2.40	756,930	161·5	162,176	156·7	750·	1⅝	79·3	—	1115·
2.50	758,540	161·	163,746	157·	750·	1¾	—	81·	1115·
3.00	760,160	162·	165,336	159·	750·	1⅝	—	81·	1128·
3.10	761,775	161·5	166,922	158·6	750·	1⅝	—	82·	1128·
3.20	763,370	159·5	168,513	159·1	—	1⅝	—	—	1144·
3.30	765,010	164·	170,143	163·	765·	1⅝	—	—	1162·
3.40	766,640	163·	171,773	163·	750·	1⅝	—	84·	1106·
3.50	768,225	158·5	173,357	151·7	750·	1¾	—	82·	1150·
4.00	769,790	156·5	174,920	156·3	760·	—	—	84·	1169·
4·10	771,430	164·	176,560	164·	770·	1⅝	—	85·	1178·
4·20	773,010	158·	178,135	157·5	765·	1¾	—	82·	1200·
4·30	774,580	157·	179,698	156·3	760·	2	—	82·	1203·
4·40	776,120	154·	181,245	153·7	760·	1¾	—	83·	1198·
4·50	777,630	151·	182,750	150·5	760·	1⅝	—	82·	1192·
5·00	779,190	156·	184,3[illegible]8	152·8	765·	1¾	—	78·2	1198·
5·10	780,695	150·5	185,814	150·6	765·	1⅝	—	78·9	1193·
5.20	782,220	152·5	187,340	151·6	750·	1¾	—	78·7	1162·
5·30	783,820	160·	188,945	160·	760·	1⅝	—	78·6	1175·
5·40	785,430	161·	190,549	160·4	765·	1¾	—	78·	1190·
5·45	786,210	—	191,284	—	—	—	—	—	—
Mean,	—	160·76	—	155·44	752·6	1 11-16	75·5	81·3	1148·5

TABLE I (*b*).—May 6th.

Time.	Revolutions. Counter.	Revolutions per Minute.	Explosion Counter.	Explosions per Minute.	Pyrometer.	Gas Pressure. Inches.	Gas Temp. F.	Room Temp. F.	Brake Load. Pounds.
7·44	786,210	—	191,284	—	—	—	—	—	—
7·50	787,130	—	191,783	—	—	—	—	—	—
8.00	788,710	158·	193,308	152·5	—	—	—	—	—
8.10	790,290	158·	194,887	157·9	700·	1½	68·	—	1084·
8.20	791,890	160·	196,457	157·	750·	1⅝	68·	—	1123·
8.30	793,470	158·	198,027	157·	750·	1¾	69·	—	1118·
8.40	795,060	159·	199,615	158·8	760·	1½	69·5	—	1151·
8.50	996,680	161·	201,185	157·	760·	1½	70·	—	1160·
9·00	798,300	162·	202,800	161·5	778·	1¾	71·	—	1178·
9.10	799,190	161·	204,400	160·	756·	1⅝	70·8	—	1185·
9.20	801,470	156.	206,958	155·8	756·	1½	71·2	—	1180·
9.30	803,030	156·	207,518	156·	760·	1½	71·5	—	1190·
9.40	804,620	160·	209,110	159·2	760·	1⅝	72·	—	1190·
9.50	806,254	162·4	210,722	161·2	765·	1¾	72·	—	1196·
10.00	807,825	157·1	212,292	157·	770·	1¾	72·	—	1189·
10.10	809,420	159·5	213,880	158·8	760·	1¾	72·	—	1189·
10.20	810,980	156·	215,440	156·	770·	1½	72·4	—	1190·
10.30	812,580	168·	217,064	162·4	780·	1¾	73·	—	1192·
10.40	814,190	161·	218,673	160·9	775·	1½	73·4	82·	1181·
10.50	815,810	162·	220,272	159·9	770·	1¾	74·4	—	1168·
11.00	817,425	161·5	221,885	161·3	770·	1¾	74·2	—	1181·
11.10	819,055	161·5	223,491	160·6	770·	2	74·2	—	1179·
11.20	820,605	155·0	225,039	154·8	755·	1¾	74·8	—	1182·
11.30	822,185	158·5	226,619	158·	760·	1¾	76·	82·	1180·
11.40	823,730	154·5	228,163	154·4	765·	2	75·8	—	1180·
11.50	825,235	150·5	229,672	149·9	760·	1⅞	76·	—	1183·
12.00	826,705	147·	231,155	147·	760·	2	76·8	86·	1180·
12.10	828,205	150·	232,655	150·	760·	1⅝	76·4	84·	1182·
12.20	829,725	152·	234,185	152·	760·	1¾	76·6	—	1174·
12.30	831,350	152·5	235,708	152·3	770·	1⅝	76·6	82·	1180·
12.40	832,835	158·5	237,288	158·	765·	1¾	76·2	84·	1190·
12.50	834,400	156·5	238,848	156·	760·	1¾	76·2	82·	1175·
1.00	835,970	157·	240,416	156·8	760·	1¾	76·6	84·	1170·
1.10	837,565	159·5	242,007	159·1	770·	1½	76·6	84·	1156·
1.20	839,185	162·	243,627	162·	770·	1¾	76·8	—	1160·
1.30	840,815	163·	245,234	161·7	770·	1⅝	77·	82·	1165·
1.40	842,445	163·	246,858	162·4	770·	1¾	77·	—	1158·
1.50	844,055	161·	248,740	158·2	755·	1½	77·6	82·	1179·
2 00	845,625	157·	250,010	157·	760·	1¾	77·2	—	1170·
2.10	847,205	158·	251,590	158·	765·	1¾	77·4	82·	1171·
2.20	848,835	163·	253,220	163·	760·	1¾	77·2	—	1172·
2.30	850,450	161·5	254,815	159·5	765·	1⅝	77·3	85·	1174·
2.40	852,070	162·	256,435	162·	770·	1¾	77·	—	1165·
2.50	853,690	162·	258,033	159·8	765·	1½	77·2	85·	1156·
3.00	855,300	161·	259,260	158·7	700·	1¾	78·	—	1158·
3.10	856,900	160·	261,213	159·3	755·	1½	77·8	86·	1150·
3.20	858,480	158·	262,798	158·	760·	1½	77·8	—	1165·
3.30	860,045	156·5	264,358	156·5	750·	1¾	78·5	87·	1158·
3.40	861,610	156·5	265,920	156·2	750·	1¾	78·	—	1148·
3.50	863,185	157·5	267,490	157·	740·	1⅝	78·	88·	1140·
4.00	864,795	161·	269,094	160·4	750·	1½	78·8	—	1125·
4.10	866,460	166·5	270,494	140·	720·	1¾	79·8	82·	1135·
4.20	868,070	161·	271,944	145·	730·	1¾	77·	80·	1815·
4.30	869,680	161·	273,344	140·	740·	1¾	77·	—	1045·
4.40	871,235	155·	274,894	155·	740·	1½	77·	—	1138·
4.50	872,830	159·5	276,474	158·	750·	1¾	76·	82·	1137·
5.00	874,435	160·5	278,034	156·	760·	1¾	76·5	82·	1149·
5.10	876,010	158·	279,587	155·3	760·	1½	77·	—	1149·
5.20	877,590	158·	281,119	153·2	760·	1¾	77·	82·	1170·
5.30	879,180	157·	282,639	152·	760·	1¾	77·2	—	1170·
5.40	880,690	151·	284,614	152·5	—	—	—	—	1200·
Mean,	—	158·73	—	156·73	758·54	1·8	75·13	82·41	1162·5

TABLE I (*c*)—MAY 7TH.

Time.	Revolutions. Counter.	Revolutions per Minute.	Explosion. Counter.	Explosion per Minute.	Pyrometer.	Gas Pressure. Inches.	Gas Temp. F.	Room Temp. F.	Brake Load. Pounds.
7.26	880,690	—	284,164	—	—	—	—	—	—
7.40	882,900	170·	285,962	134·	640	1½	68·8	64	1030·
7.50	884,505	160·5	287,543	158·1	700	1½	68·2	—	1051·
8.00	886,145	164·	289,181	163·8	720	1½	70·	72	1051·
8.10	837,785	164·	290,820	163·9	730	1¾	71·	—	1060·
8.20	88,940	161·5	292,424	160·4	740	1¾	71·2	74	1087·
8.30	890,945	154·5	293,964	154·	740	1¾	71·8	—	1139·
8.40	892,490	165·5	295,540	157·6	760	1¾	71·6	71	1154·
8.50	894,108	161·8	297,130	159·	760	1¾	71·6	—	1182·
9·00	895,690	158·2	298,710	158·	750	2	71·9	75	1166·
9·10	897,250	156·	300,267	155·7	750	3	71·9	80	1155·
	Engine stopped at 9·11 because indicator motion string broke.								
9.30	899,049	—	301,578	—	690	1½	74·1	82	1119·
9.40	900,475	142·6	302,986	140·8	740	1½	72·8	80	1123.
9.50	902,250	177·5	304,733	174·7	750	1½	72·5	78	1151·
10.00	903,839	158·9	306,318	158·5	760	1½	72·2	78	1169·
10.10	905,455	161·6	307,925	160·7	760	1½	72·2	78	1153·
10.20	907,069	164·4	309,525	160·	760	1½	72·3	78	1200·
10.30	908,680	161·1	311,136	161·1	770	1½	72·6	79	1190·
10.40	910,315	163·5	312,785	162·9	760	1½	72·8	80	1200·
10.50	913,962	163·2	314,372	161·5	750	1½	73·1	79	1150·
11.10	915,161	159·9	317,569	159·2	740	1½	73·1	77	1110·
11.20	916,759	159·8	319,160	159·1	750	1½	73·2	76	1190·
11.30	918,374	161·5	320,774	161·4	760	1¾	73·4	77	1150·
11.40	919,929	155·5	322,329	155·5	750	1¾	73·3	78	1185·
11.50	921,840	155·1	323,859	153·	760	1½	73·2	78	1165·
12.00	923,148	166·8	325,525	166·6	760	1¾	73·7	77	1140·
12.10	924,668	152·	327,043	152·	760	1½	74·	77	1183·
12.20	926,278	161·	328,635	161·	764	1¾	74·3	80	1183·
12.30	927,795	147·7	330,132	147·7	764	1⅝	74·5	80	1181·
12.40	929,548	179·3	331,924	179·2	758	1¾	74·7	78	1178·
12.50	931,110	156·2	333,485	156·1	745	1¾	74·5	79	1154·5
1.00	932,716	160·6	335,091	160·6	752	1¾	74·4	80	1155·
1.10	934,355	163·9	336,729	163·8	760	1½	74·4	80	1153·
1.20	935,990	163·5	338,364	163·5	760	1¾	74·6	80	1176·
1.30	937,610	162·	339,974	161·	760	1¾	74·8	77	1190·
1.40	939,155	154·5	341,512	153·8	750	1¾	75·1	78	1160·
1.50	940,740	158·5	343,096	158·4	745	1¾	75·	79	1155·
2·00	942,320	158·	344,676	158·	750	1¾	75·	80	1160·
2.10	943,940	162·	346,296	162·	760	—	75·	81	1140·
2.20	945,600	166·	347,948	165·2	750	1¾	75·	80	1150·
2.30	947,200	160·	349,546	159·8	755	1⅝	74·8	78	1160·
2.40	948,860	166·	351,196	165·	750	1¾	74·8	82	1100·
2.50	950,538	167·8	352,864	165·8	740	1¾	74·9	78	1113·
3.00	952,193	165·5	354,504	164·	750	1⅝	75·	80	1142·
3.10	953,831	163·8	356,141	163·7	752	1⅜	75	80	1163·
3.20	955,487	165·6	357,792	165·1	754	1½	75·	80	1175·
3.30	957,109	162·2	359,412	162·	736	1¾	75·1	80	1117·
3.40	958,680	157·1	360,980	156·8	720	1¾	75·1	80	1147·
3.50	960,397	171·7	362,696	171·6	727	1¾	75·2	78	1127·
4.00	961,930	153·3	364,225	152·9	740	2	75·3	78	1129·
4.10	963,700	177·	365,989	176·4	740	2	75·	80	1143·
4.20	965,340	164·	367,625	163·6	742	2	75·1	78	1144·
4.30	966,784	160·4	369,064	159·9	740	2	75·2	80	1154·5
4.40	968,371	158·7	370,650	158·6	740	2	75·2	78	1158·
4.50	969,938	156·7	372,216	156·6	739	2	75·4	78	1169·
5.00	971,512	157·4	373,790	157·4	748	1½	75·3	78	1176·
5.10	973,125	161·3	375,402	161·2	747	1½	75·4	79	1162·
5.20	974,657	153·2	376,929	152·7	744	1¾	75·6	78	1068·
5.30	976,238	158·1	378,507	157·8	721	1¾	—	78	1159·5
5.40	977,836	159·8	380,104	159·7	735	1⅝	—	—	1155·
Mean,	—	160·9	—	160·43	747·3	1¾	73·4	80·2	1138·3

Thus, on May 5th, the average explosions per minute, from 9 A.M. to 5.40 P.M., was 155·55. The number of explosions before 9 A.M. and after 5·40 P.M. amounted to 11,623, which was the equivalent of 74.73 minutes at the average above found, so that the total running time for that day is taken as 9 hours 54·73 minutes. On May 6th, from 8 A.M. to 5·10 P.M. was taken as the time from which to determine the average number of explosions per minute, and the total time for this day was 9 hours 49·96 minutes. On May 7th, as the engine was stopped during the test for the purpose of securing the indicator string, the total time amounted to 10 hours and 4 minutes, and the total time of running for the three days amounted to 1788·69 minutes, with an average number of explosions 157·57.

From this table was also worked out the brake horsepower. The prony brake was arranged with a weight on the north side and another weight on the south side, the weight on the north side resting on a platform scale and being so arranged that the pressure brought by the friction of the brake was downward on the scales. The weight on the north side averaged 628 pounds, while the weight on the south side averaged 469 pounds. The circumference of the pulley was 15 feet 3 inches, and the distance from the pulley where the circumference was measured to the knife edge to which the north weight was attached was 7¾ inches, and the distance from the pulley to the knife edge to which the south weight was attached was 7½ inches, or of the lever arm of the south weight was 3·072 feet, and of the north weight was 3·073 feet, and the brake horse-power was determined from the following formulæ:

$$\text{B.H.P.} = \frac{6{\cdot}2832\,N(3{\cdot}073\,w - [3{\cdot}073 \times 628 - 3{\cdot}052 \times 469])}{33{,}000}$$

N being the number of revolutions per minute;
w, the load on the scales in pounds.

The average brake horse-power for the first day, May 5th, was 92·73; for the second day, May 6th, was 92·85, and for the third day, May 7th, was 91·82, the average for the entire time was 92·49.

For the entire running time, the average number of explosions per minute was 157·57. The average number of revolutions was 160,145. The average reading of the pyrometer was 752·81. The average pressure of the gas was ·062 pounds, the barometer being 14·686 pounds. The average temperature of the gas was 74·°68 F.

Table II gives the indicated horse-power for each of the cards as taken during the time of the test, and it will be noted that only those cards were put down that were taken during the time the engine was supposed to be running under uniform conditions. Indicators were fitted to both the lower and the upper cylinders, with springs in them which were good to over 300 pounds. During the preliminary tests which were made on the 3d and 4th of May, it was found that these indicators would not do the work, either the springs or the pencil bar being broken from the violence of the explosion. After repairing them, the same results occurred again, and we were obliged to use a Thompson indicator with a one-quarter square inch piston which had been in use in the works for a considerable time. It was found that if the indicator was allowed to remain on the engine between the time of taking successive cards, the heat conducted from the cylinder was sufficient to melt the solder holding the spring to the screw ends, but after the test was commenced, the indicators were removed after taking each card and there was practically no difficulty in this way. The indicator piston was not at all tight, or if reasonably tight at the beginning of the test was not so at the end. After the test the indicator was put on a steam boiler and the spring calibrated; as there was considerable leakage past the piston, a mercury column was attached to the upper side of the piston, and allowance made for this pressure in determining the scale, which was found to be practically 190 pounds to the inch. It will thus be seen that there is not a very large amount of confidence to be placed in the indicated horse-power, although the results are probably fairly correct.

TABLE II (*a*)—May 5th.—*Indicated Horse-power.*

Top Cylinder.			Bottom Cylinder.		
Card.	Time.	I.H.P.	Card.	Time.	I.H P.
11	9.00	64·86	10	8.45	62·37
13	9.30	66·78	12	9.15	66·20
15	10.00	66·26	14	9.45	65·78
17	10.30	68·78	16	10.15	70·58
19	11.00	66·84	18	10.45	70·16
21	11.30	70·88	20	11.15	72·22
23	12.00	64·86	22	11.45	67·09
25	12.30	63·92	24	12.15	66·16
27	1.00	66·73	26	12.45	69·71
29	1.45	64·19	28	1.38	67·09
31	2.15	61·98	30	2.00	60·69
33	2.45	60·27	32	2.30	57·45
35	3.15	66·21	34	3.00	68·44
37	3.45	59·25	36	3.30	68·65
39	4.15	66·51	38	4.00	68·40
41	4.45	57·13	40	4.30	64·15
43	5.15	60·26	42	5·00	65·34
45	5.42	62·17	44	5.30	67·26
Mean, ...	—	64·36	—	—	66·80

Total I H. P., ... 131·16
Mean brake horse-power, ... 92·73

TABLE II (*b*)—May 6th.—*Indicated Horse-power.*

Top Cylinder.			Bottom Cylinder.		
Card.	Time.	I.H.P.	Card.	Time.	I.H.P.
46	8.05	57·62	47	8.15	56·95
48	8.30	55·86	49	8.45	60·88
50	9.00	63·23	51	9.15	63·31
52	9.30	57·20	53	9.49	61·48
54	10.00	60·49	55	10.15	67·02
56	10.30	59·14	57	10.45	63·76
58	11.00	61·47	59	11.15	68·49
60	11.30	59·31	61	11.45	59·84
62	12.00	60·84	63	12.15	60·41
64	12.30	60·86	65	12.45	65·04
66	12.57	61·10	67	1.15	63·75
68	1.30	64·58	69	1.45	66·45
70	2.00	60·54	71	2.15	62·13
72	2.30	65·92	73	2.45	65·80
74	3.00	62·28	75	3.15	63·77
76	3.30	59·26	77	3.45	61·87
78	4.00	57·04	—	—	—
79	4.30	56·70	—	—	—
80	5.00	58·73	—	—	—
Mean, ...	—	59·81	—	—	63·08

Total I.H.P., ... 122·89
Mean brake horse-power, ... 92·85

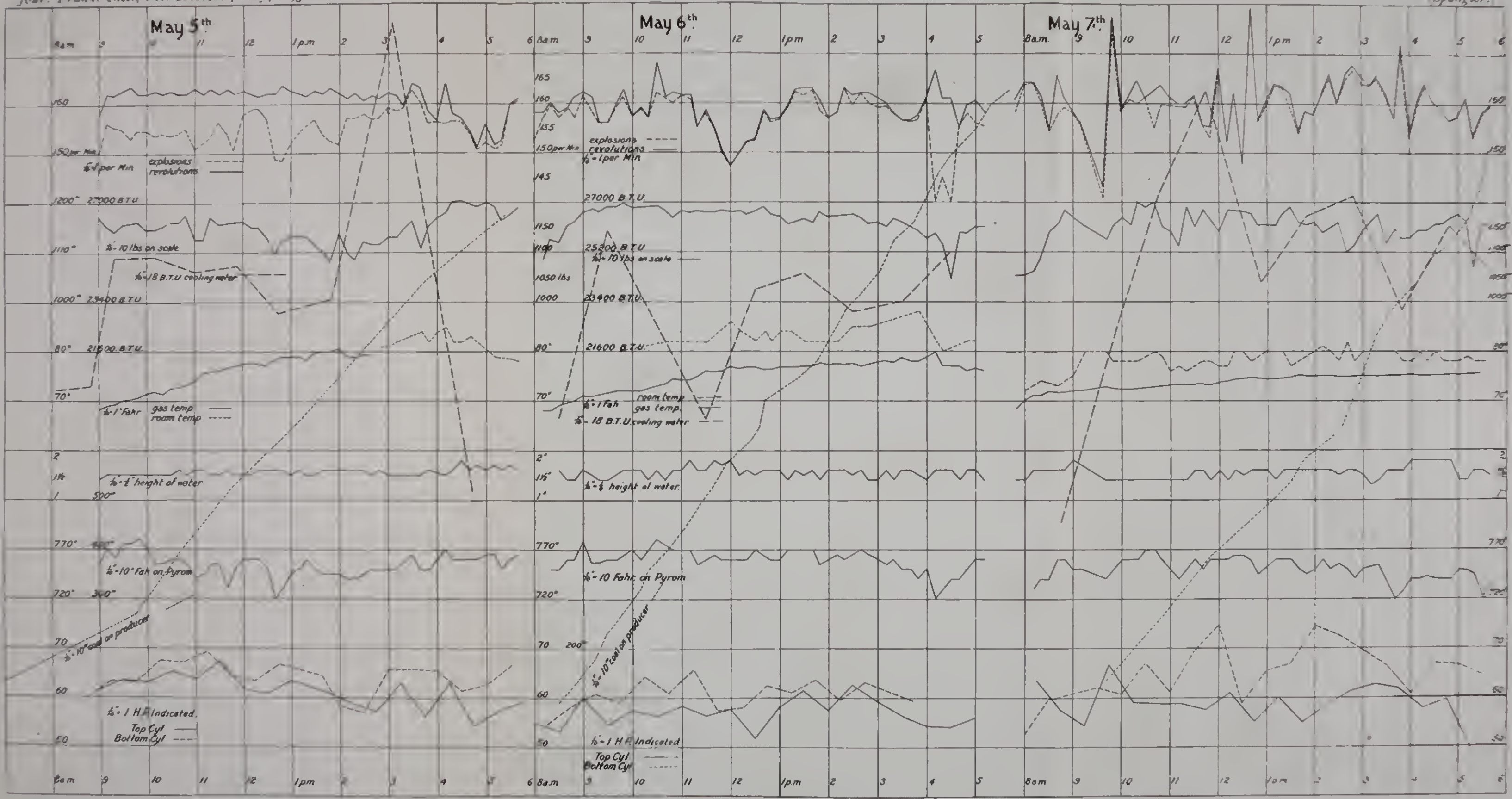

Fig. 5.—Record of Tests.

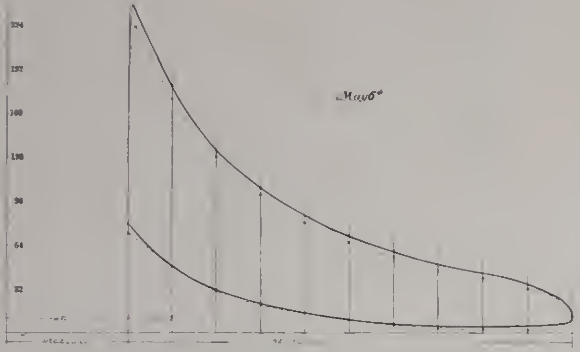

Fig. 6.—Average Indicator Card for each Cylinder during May 6.

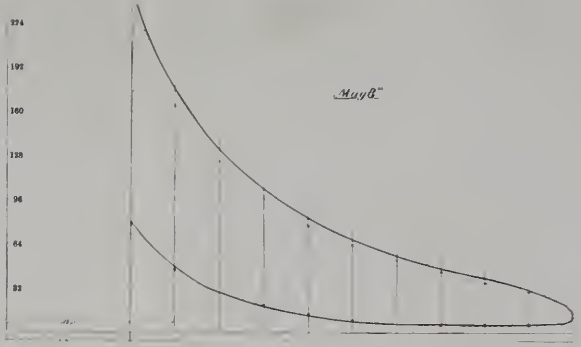

Fig. 8.—Average Indicator Card for each Cylinder during May 8.

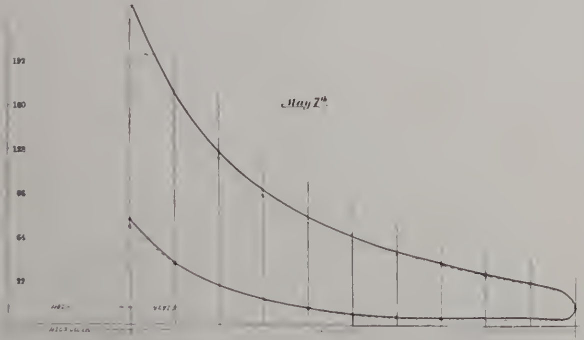

Fig. 7.—Average Indicator Card for each Cylinder during May 7.

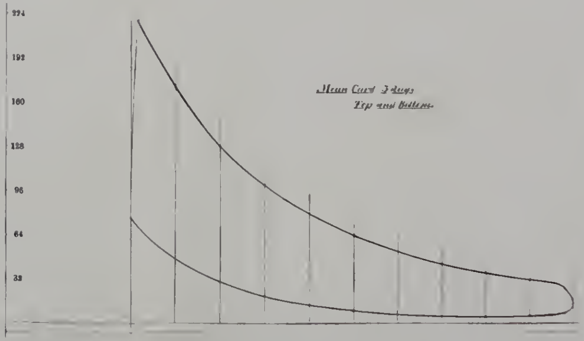

Fig. 9.—Average Indicator Card from both Cylinders during May 6, 7, and 8, 1892.

TABLE II (*c*)—MAY 7TH.—*Indicated Horse-power.*

TOP CYLINDER.			BOTTOM CYLINDER.		
Card.	Time.	I.H.P.	Card.	Time.	I.H.P.
81	7.45	44·28	82	8 00	54·43
83	8.15	66·59	84	8.35	62·23
85	8.47	60·54	86	9.00	Indicator string broke.
87	9.05	57·08	88	9.30	64·72
89	9.45	70·10	90	10 00	63·31
91	10.15	62·19	92	10.30	69·73
93	10.45	61·89	94	11.01	63·56
95	11.15	61·86	96	11.30	72·38
97	11.45	60·60	98	12.00	77·90
99	12.15	65·14	100	12.30	61·30
101	12.45	58·00	102	1.00	68·20
103	1.15	63·26	104	1.30	69·71
105	1.45	57·64	106	2.00	77·68
107	2.22	61·25	108	2.30	75·79
109	2.45	64·42	110	3.00	72·58
111	3.15	65·92	112	3.30	69·27
113	3.45	64·17	114	4.00	63·25
115	4.15	60·92	116	4.30	69·84
117	4.45	62·58	118	5.00	69·77
119	5.15	52·26	120	5.30	67·41
Mean, ...	—	61·10	—	—	67·96

Total I.H.P., ... 129·06
Mean brake horse-power, ... 91·82

Figs. 6, 7, 8 and *9* are the average of all the indicator cards taken. *Fig. 6* shows the average of the cards from both cylinders taken on May 5th, and *Figs. 6* and *7* for May 7th and 8th. *Fig. 9* is the average for all the cards taken. It will be noted that the average cards from the bottom cylinder are invariably larger than those from the top cylinder and an examination of Table VIII shows that the amount of air supplied to the bottom cylinder was more nearly the amount required for complete combustion than that supplied to the top one.

The size of the cylinder was practically 14⅝ inches diameter by 25-inch stroke. After the test the cylinder and the clearance spaces were filled with water.

Table III shows the volume of both cylinders, together with the clearances. The displacement of the bottom cylinder was found to be 4211·36 cubic inches and the clearance 1170·19, or 27·98 per cent. The displacement of the top cylinder was found to be 4247·94 cubic inches, and the clearance 1187·09 cubic inches, or 27·94 per cent. The volume as found from filling the cylinder with water, was used in determining the horse-power.

TABLE III.—*Clearance Determination.*

TEMPERATURE OF WATER, 61° TO 62° F.

No.	Before.	After.	Net.	Volume.
		Bottom Valve.		
1	27·56	21·62	5·94	164·5974 cubic inches.
		Top Valve.		
2	24·17	18·33	5·84	161·8264 cubic inches.
		Top Cylinder Clearance.		
2	26·07	8·78	17·29	(38·58 — 1·58) × 27·71 = 1025·27 cubic inches.
3	27·09	8·79	18·32	
4	28·63	25·66	2·97	
			38·58	
		Top Cylinder Displacement.		
1	29·65	8·81	20·84	
2	27·62	8·77	18·85	
3	27·97	8·77	19·20	
4	25·66	8·80	16·86	153·3 × 27·71 = 4247·943 cubic inches.
1	27·92	8·83	19·09	
2	28·50	8·78	19·72	
3	28·65	8·80	19·85	
4	29·98	11·09	18·89	
	225·95	72·65	153·30	
		Filling Pipe.		
—	18·32	16·74	1·58	
		Bottom Cylinder Clearance.		
1	30·34	8·82	21·52	(37·87 — 1·58) × 27·71 = 1005·5959 cubic inches.
2	29·95	13·60	16·35	
	60·29	22·42	37·87	
		Bottom Cylinder Displacement.		
3	26·64	10·37	16·27	
4	27·57	10·91	16·66	
1	26·33	9·31	17·02	
2	27·52	9·30	18·22	
3	27·23	9·10	18·13	151·98 × 27·71 = 4211·3658 cubic inches.
4	26·96	9·23	17·73	
1	27·65	9·42	18·23	
2	27·61	9·45	18·16	
3	27·13	15·57	11·56	
	244·64	92·66	151·98	

Total clearance top cylinder, ... 1187·0946 cubic inches, 27·94 per cent.
Total clearance bottom cylinder, ... 1170·1933 cubic inches, 27,978 per cent.

TABLE IV (*a*)—MAY 5TH.—*Jacket Water.*

Time.	Weight Water.	Temp. Disc.	Temp. Inlet.	Pounds C.	B.T.U.
		°C.	°C.		
8.05	664	37·33	16·91	13,280	5976·
8.50	611	46·58	28 83	10,845	4880·25
9.22	645	53·75	32·5	13,775	5171·75
10.10	678	55·5	35·	13,900	6255·
10.58	680	56·	36·	13,600	6120·
11.54	680	57·66	36·5	13,710	6169·5
12.45	687	56·33	37·75	12,768	5746·2
1.52	686	57·25	38·25	13,034	5865·3
3.06	673	60·00	32·33	18,642	8388·9
4.43	700	40·00	23·66	11,666	5250·

TABLE IV (*b*)—MAY 6TH.—*Jacket Water.*

Time.	Weight Water.	Temp. Disc.	Temp. Inlet.	Pounds C.	B.T.U.
		°C	°C.		
8.25	664	46·66	30·	10,762	4843·
9.25	801	39·	21·	14,418	6488·
10.25	427	59·	29 66	12,518	5633·
11.25	531	64·	34·	10,620	4779·
12.25	631	57·	36·	13,261	5967·
1.25	698	56·33	36·92	13,551	6098·
2.25	524	59·33	34·92	12,787	5758·
3.25	520	63·	38·	13,000	5850·
4.25	691	56·66	37·13	13,941	6273·
5.25	697	57·5	38·	12,894	5802·

TABLE IV (*c*)—MAY 7TH.—*Jacket Water.*

Time.	Weight Water.	Temp. Disc.	Temp. Inlet.	Pounds C.	B.T.U.
		°C.	°C.		
8.50	521	50·33	32·	9,550	4297·
9.50	700	49·66	32·	12,361	5562·
10.50	703	54·5	33·	15,116	6802·
11.50	703	53·83	34·33	13,729	6178·
12.50	701	53·00	34·	13,380	6021·
1.50	532	61·66	34·	14,715	6622·
2.50	769	41·66	22·	15,119	6803·
3.50	694	50·5	32·	12,839	5817·
4.50	519	61·	33·	14,529	6538·
5.35	696	52·	33·83	13,347	6006·

Mean B.T.U., May 5th, 5904·9. May 6th, 5742·5. May 7th, 6218·1.

Table IV, *a*, *b* and *c*, shows the records of the water used in the jacket. The first column gives the time when the water began to fill the tanks. The second column gives the weight of water in pounds that flowed into the tank in four minutes. The third and fourth columns give the temperatures of the inflowing and discharge water in degrees C., each number being the mean of three readings. The fifth column gives the result in pound degrees found by multiplying the temperature change by the pounds discharged, and the sixth column gives the number of British thermal units carried away per minute, being nine-twentieths of the fifth column.

Table V gives the quantity of coal that was used each day of the test, amounting to 1069·6 pounds on May 5th, 1324·2 on May 6th, 1263·6 on May 7th, a total of 3157·4 pounds for the entire time.

TABLE V.—*Coal.*

Time.	Weight.	Time.	Weight.	Time.	Weight.
May 5th.		10 40	29·5	*May 7th.*	
A.M.		11.06	50·6	A.M.	
7·00	129·8	11.25	48·4	8.25	134·4
9.45	136·3	11.40	33·0	10·00	118 4
10.40	127·6	11.55	54·6	11.00	127·2
11.44	131·	P.M.		P.M.	
P.M.		12.20	48·7	1.00	125·1
1.15	140·3	12.35	27·2	1.30	32·7
2·30	139·3	12.40	53·5	1.45	51·2
3·45	135·2	1.23	42·	2.13	28·8
5.22	130·1	1.48	34·1	2.32	22·3
		2.05	56·2	2.47	59·1
Total, . . 5-5 =	1069·6	2.23	49·	3.01	61·3
		2.39	32·3	3.15	65·6
		3.03	45·2	3.35	55·1
May 6th.		3.24	54·8	4.05	54·6
A.M.		3.43	34·0	4.30	59·
7.38	42·7	4.00	49·8	4.51	20·7
8.28	47·5	4.15	50·	5.18	59·
8.56	40·2	4.30	34·	5.22	31·1
9.15	49·	5.00	50·4	5.30	28·5
9.26	50·1	5.19	49·7	5.35	54·4
9.48	34·1	5.40	30·	5.40	75·1
10.09	54·7				
10.20	48·9	Total, . . 5-6 =	1324·2	Total, . . 5-7 =	1263·6

Table VI shows in the first column the time at which the sample of gas was taken. The apparatus used was the Elliott, in which the readings before the explosions indicate the differences between 100 cubic centimetres and the quantity of gas in the apparatus. In the explosion tube the numbers represent the total volume used. The second column in the table indicates the reading of the original gas. The third column, headed KOH, is the reading after potassic hydrate has been added, and the difference between that column and the one preceding is the amount of CO_2 which was present in the gas. The fourth column represents the reading after the oxygen has been removed; the fifth column the reading after the carbonic oxide has been removed. The sixth column represents the quantity of the remaining gas that was taken for explosion. The next column represents the quantity of gas after a certain proportion of air has been added, and the difference between the last two columns is the quantity of air added. The next column represents the quantity of gas after the mixture has been exploded, the hydrogen having disappeared. The last column is the quantity of gas after the carbonic acid has been taken out, and practically represents nitrogen. The remaining columns represent the number of cubic centimetres of the different constituents of the original gas.

TABLE VI.—*Gas Analyses.*

	READINGS.				CUBIC CENTIMETRES.											
Time.	Orig. Vol.	KOH.	Pyro.	Cu_2Cl_2.	Before exp.	Air Added.	After exp.	KOH.	Gas.	CO_2.	O.	CO.	Rem.	Before exp.	Contraction.	CO_2.
May 5th.																
8.55	11·2	14·2	14·2	36·1	12·2	25·2	—	—	—	—	—	—	—	—	—	—
9.27	4·3	6·9	6·9	24·5	16·7	38·2	—	—	—	—	—	—	—	—	—	—
11.10	4·	6·3	6·3	29·6	22·3	48·	44·5	44·3	96·	2·3	0	23·3	70·3	22·3	3·5	·2
2.05	8·5	12·6	20·7	36·5	11·	25·4	—	—	—	—	—	—	—	—	—	—
4.34	·8	4·9	5·1	22·5	16·2	42·4	39·5	38·8	99·2	4·1	·2	17·4	77·5	16·2	2·9	·7
May 6th.																
8.04	5·9	10·1	10 1	36·1	15·6	36·	—	—	—	—	—	—	—	—	—	—
9.02	4·1	6·1	6·2	36·1	11·	20·5	—	—	—	—	—	—	—	—	—	—
11.25	5·5	7·5	7·5	35·9	21·5	28·7	25·5	24·5	94·5	2·	—	28·4	64·1	21·5	3 2	1·
1.41	11·5	14·9	14·9	39·8	24·8	33·2	29·9	—	88·5	3·4	—	24·9	60·2	24·8	3·3	—
3.15	10 8	14·3	14·8	39·7	24·2	33·1	30·	—	89·2	3·5	·5	24·9	60·3	24·2	3·1	·5
May 7th.																
7.00	10·2	14·5	14·5	38·7	—	—	—	—	89·8	4·3	—	24·2	—	—	—	—
8.25	10·4	13·3	13·3	39·5	32·	45·2	40·	39·	89·6	2·9	—	26·2	60·5	32·	5·2	·1
10.45	7·4	10·4	10·4	36·2	43·1	56·7	51·3	—	92·6	3·	—	25·8	63·8	43·1	5·4	—
2.03	10·4	15·4	15·8	38·8	37·3	50·2	44·4	43·8	89·6	5·	—	23·	61·2	37·3	5·8	·6
3.55	6·4	12·7	13·3	34·8	47·7	61·6	58·	57·5	93·6	6·9	—	21·5	65·2	47·7	3·6	·5

The work is continued beyond this in only those cases in which the readings were completed. The other cases are here given to show that those used were about mean values.

Table VII is a continuation of those portions of Table VI, in which a complete analysis was made, and reduces the gas into its percentage by volume.

Table VIII gives the analysis of the top and bottom exhausts, the headings of the columns sufficiently explaining the quantities entered. The Elliott apparatus was used on part of the work, and on the balance the readings beginning at 100 or 72 being the latter.

TABLE VII.—*Gas Analyses continued.*

PER CENT. VOL.

	CO_2	O	CO	H	CH_4	N
May 5th.						
11.10	2·40	—	24·27	7·46	·66	65·21
4.34	4·13	·20	17·54	4·78	3·40	69·95
May 6th.						
11.25	2·12	—	30·05	2·58	3·16	62·09
3.15	3 92	·56	27·92	3·91	1·40	62·29
May 7th.						
8.25	3·23	—	29·24	4·51	2·10	60·92
2.03	5·58	·45	25·65	5·60	1·10	61·62
3.55	6·73	·64	22·97	2·71	·73	66·22
	4·02	·26	25·38	4·51	1·79	64·04 = 100

				Weight in 100 Pounds Gas.			
	% Vol.		*% Wt*	*C*	*O*	*H*	*N*
CO_2, ...	4·02 × 22 =	88·41 =	6·50	1·77	4.73	—	—
O, ...	·26 × 16 =	3·16 =	·23	—	·23	—	—
CO, ...	25·38 × 14 =	355·32 =	26·08	11·18	14·90	—	—
H, ...	4·51 × 1 =	4·51 =	33	—	—	·33	—
CH_4, ...	1·79 × 8 =	14·32 =	1·05	·79	—	·26	—
N, ...	64·04 × 14 =	896·56 =	65·81	—	—	—	65·81
		1362·31	100·00	13·74	19·86	·59	65·81

Table IX gives on the left-hand side the average composition by weight and volume of the exhaust gas, and on the right-hand the composition of enough of the gas by weight to include 13·74 per cent. of carbon and ·59 per cent. of hydrogen, which was the amount in 100 parts of the original gas; that is, each 100 parts of the original gas required 126·64 parts of air by weight, making 226·64 pounds of exhaust gas. The oxygen and nitrogen added, are in the proportion of 22·5 : 77·5, which is about the proportion they should have had in the air added.

Table X shows the variation in condition of the fire during the time of the test; the first column showing the time at which the reading was taken; the second the distance from the bottom of the rod to the bottom of the fire; the third the distance from the bottom of the rod to the top of the fire, and the fourth the thickness of the fire. The gas meter was attached to the pipe leading to the second scrubber, as shown in *Fig. 3*, by means of which the attendant noted the condition of the gas. The total quantity of gas used in this meter was 2,530 cubic feet. The power necessary to run the blower was found to be ·085 horse-power on one inch of water, ·28 for 6½ inches of water and ·431 for 9¼ inches of water.

TABLE VIII.—*Exhaust Analyses.*

Time.	Readings.				Volumes.				Per Cent. Volumes.				
	Orig. Vol.	KOH	Pyro.	Cu_2Cl_2	Gas.	CO_2	O	CO	Gas.	CO_2	O	CO	N
Top Exhaust													
May 5th.													
10.20	3·	16·4	19·7	22·7	97·	13·4	3·3	3·	100	13·6	3·4	3·1	
5.15	1·6	17·1	19·1	18·7	98·4	15·5	2·	—	100	15·7	2·1	—	
May 6th.													
10.55	7·	20·5	23·	23·	93·	13 5	2·5	—	100	14·5	2·6	—	
2.55	100·	84·6	81·6	100·	15·4	3·	—	—	100	15·4	3·	—	
4.47	72·	19·9	24·4	92·8	12·2	4·8	—	—	100	13·1	5·2	—	
May 7th.													
9.10	100·	84·8	81·	81·	100·	15·2	3·8	—	100	15·2	3·8	—	
10.15	9·8	21·9	24·8	24·8	90·2	12·1	2·9	—	100	13·4	3·2	—	
11.45	9·3	23·8	25·5	25·5	90·7	14·5	1·7	—	100	15·9	1·8	—	
1.20	12·4	25·1	28·7	87·6	12·7	3·6	—	—	100	14·5	4·2	—	
2.55	12·	25·5	28·2	88·	13·5	2·7	—	—	100	15·3	3·1	—	
5.30	10·2	24·	27·8	27·7	89·8	13·8	3·8	—	100	15·4	4·1	—	
Bottom Exhaust.													
May 5th.													
11.35	4.5	19·5	29·1	27·	95·5	15·	8·6	—	100	15·7	9·0	—	
12.25	2.1	17·3	20·1	16·2	97·9	15·2	2·8	—	100	15·5	2·9	—	
4.00	8·1	21·2	22·	21·7	91·9	13·1	1·	—	100	14·2	1·1	—	
May 6th.													
10.55	100·	83·2	83·2	82·7	100·	16·8	—	·5	100	16·8	—	·5	
1 08	10·4	25·1	26·0	26·2	89·6	14·7	·9	·2	100	17·5	1·0	·2	
2.55	4·6	21·0	21·7	22·9	95·4	17·4	·7	1·2	100	18·2	·7	1·2	
May 7th.													
9.10	9·9	25·	26·4	26·4	90·1	15·1	1·4	—	100	16·7	1·5	—	
11.45	100·	82·8	81·6	82·2	100·	17·2	1·2	·6	100	17·2	1·2	·6	
12.30	9·	23·3	24·5	24·5	91·	14·3	1·2	—	100	15·7	1·4	—	
3.25	11·3	25·7	26·5	26·5	88·7	14·7	·8	—	100	16·6	·1	—	
4.47	100·	82·	82·	82·	100·	18·	—	—	100	18·	—	—	
4.55	3·8	18·6	22·7	22·	96·2	14·8	4·1	—	100	15·4	4·2	—	
Mean of top and bottom, ...									100	15·60	2·24	·23	81·93

TABLE IX.—*Weight of Exhaust Gas Corresponding to One Hundred Pounds of Producer Gas*

	Per Cent. Volume.	Per Cent. Weight.	WEIGHT IN 100 POUNDS GAS.			WEIGHT CORRESPONDING TO 100 POUNDS ORIGINAL GAS, OR 13·74 C + ·59 H.			
			C	O	N	C	O	N	H
CO_2, ...	15·60	22·44	6·12	16·32	—	13·54	36·11	—	—
O, ...	2·24	2·34	—	2·34	—	—	5·18	—	—
CO, ...	·23	·22	·09	·13	—	.20	·29	—	—
N, ...	81·93	75·00	—	95·00	95·00	—	—	165·94	—
	100·00	100·00	6·20	18·79	75·00	—	—	—	—
					5·38 H_2O	—	4·79	—	·59
From 100 pounds original gas we have = 226·64 exhaust =						13·74	46·37	165·94	·59

TABLE X.—*Height of Fire and Ash in Producer.*

Time.		Depth of Fire.		
May 4th.		*inches.*	*inches.*	*inches.*
5.45 P.M.	Bottom of rod to top of ashes, .	14¼	39¼	25·
May 5th.				
6.50 A.M.	. . . .	14·	34½	20½
8.35	. . . .	—	—	Fire raked.
10.00	. . . .	—	—	Fire raked.
10.07	. . . .	12·	32·	20·
1.55 P.M.	. . . .	—	—	Fire raked.
2.00	. . . .	18·	30·	12·
5.00	. . . .	19·5	40·	20·5
6.00	. . . .	19·	40·	21·
May 6th.				
7.30 A.M.	. . . .	13·5	24·	10·5
10.30	. . . .	18·	32·	14·
12 40 P.M.	. . . .	19·	43·	24·
4.30	. . . .	20·	41·	21·
5.40	. . . .	22·	41·5	19·5
May 7th.				
7.15 A.M.	(*Note*—Blast was on 15 minutes.)	20·	25·	5·
11.00	. . . .	18·5	37·	18·5
12.30 P.M.	. . . .	20·	41·	21·
1.30	. . . .	18·	38·	20·
2.30	. . . .	20·	38·	18·
3.30	. . . .	12·5	36·5	24·
4.30	. . . .	18·	42·	24·
5.30	. . . .	18·	43·	25·
5.50	. . . .	18·	44·	26·

At the end the distance from the top of producer to top of fire was 3 feet 6 inches.

GAS METER—CONNECTED TO BURNER.

	Cubic Feet.
May 5th, 7 A.M.,	500
6th, 7 A.M.,	1,340
7th, 7	2,190
7th, 6 P.M.,	3,030
Total	2,530
Average	84·8 cubic feet per hour.

The following will give the calculations to determine the efficiency of the plant and the different portions of it, together with the amount of coal used per horse-power:

Total coal used, = 3657·4 pounds.
Time, = 1788·69 minutes.
Explosions per minute, = 157·57
Total carbon, $3657·4 \times \frac{84·76}{100}$ = 3100·01 pounds.
Gas used in meter, = 2,530 cubic feet.

Comp. of gas by vol. and wt. =	*Volume.*		*Weight.*	
	CO_2, 4·02		6·5	
	O, ·26		·23	
	CO, 25·38	C = 15·60	26·08	total C = 13·74
	H, 4·51		·33	
	CH_4, 1·79		1·05	
	N, 64·04		65·81	

Mean barometer 29 90 in. mercury, = 14·686 pounds.
Meter pressure, gas, = ·062 pounds.
Temperature gas, = 74°·68 F.
Total absolute pressure gas, = 14·748 pounds.

Weight of carbon in one cubic foot of gas at 14·748 pounds, 74°·68 F.

$$= ·071128 \times \frac{14·748}{14·7} \times \frac{492·66}{535·34} \times ·1560 = ·0102446 \text{ pounds.}$$

[Haswell, p. 215.]

Total carbon weight used in meter = ·0102446 × 2,530 = 25·92 pounds.
Carbon chargeable to engine = 3100·01 — 25·92 = 3074·09 pounds.

Coal used for engine

$$= \frac{3074·09}{·8476} = 3,626 \text{ pounds.}$$

	Per Cent.		
Composition of coal,	4·20 moisture,		
	6·88 volatile and combustion	Total carbon 84·76 per cent. or approximately	5·80 C H_4 1·73 H
	80·41 fixed C.		
	8·51 ash.		

Heat obtainable from one pound of coal (containing ·8476 pounds carbon).

·0580 CH_4 × 23,883 . . . . = 1385·214
·0173 H × 62,032 . . . . = 1073·154
·8041 C × 14,500 [Wilson, p. 251.] . . . . = 11659·450

Total . . . . 14117·818 B.T.U.

COMPOSITION OF GAS IN PRODUCER CONTAINING ·8476 POUNDS C.

$$\left.\begin{array}{ll} & \textit{Per Cent. Weight.} \\ CO_2, \ldots\ldots\ldots\ldots = & 6{\cdot}5 \\ O, \ldots\ldots\ldots\ldots = & {\cdot}23 \\ CO, \ldots\ldots\ldots\ldots = & 26\ 08 \\ H, \ldots\ldots\ldots\ldots = & {\cdot}33 \\ CH_4, \ldots\ldots\ldots\ldots = & 1{\cdot}05 \\ N, \ldots\ldots\ldots\ldots = & 65{\cdot}81 \\ \hline & 100{\cdot} \end{array}\right\} \times \frac{{\cdot}8476}{13{\cdot}74} = \left\{\begin{array}{r} {\cdot}404 \\ {\cdot}014 \\ 1{\cdot}609 \\ {\cdot}020 \\ {\cdot}065 \\ 4{\cdot}060 \\ \hline 6{\cdot}172 \end{array}\right.$$

CO_2, ... ·404
O, ... ·014 [Wilson]
CO, ... 1·609 × 4,328 = 6963·75
H, ... ·020 × 62,032 = 1240·64
CH_4, ... ·065 × 23,883 = 1552·40
N, ... 4·060 —

Heat in producer gas per pound coal, ... 9756·79 B.T.U.

Amount of carbon per explosion approximately

$$= \frac{\text{total C received}}{\text{exp.} \times \text{time}} = \frac{3074{\cdot}09}{157{\cdot}57 \times 1788{\cdot}69} = {\cdot}010907$$

Gas per explosion

$$= \frac{100}{13{\cdot}74} \times {\cdot}010907 = {\cdot}07938$$

Air per explosion

$$\frac{126{\cdot}64}{13{\cdot}74} \times {\cdot}010907 = {\cdot}09963$$

TO DETERMINE WEIGHT OF 1 CUBIC FOOT GAS AT 14·748 POUNDS, 74°·68 F.

Moisture in gas, pressure ·8579 inch mercury = ·4214 pounds per square inch. [Stewart, p. 436.]

Pressure of dry gas = 14·3166 pounds temperature, 74°·68 F.
1 cubic foot H at 14·7 pounds, 32° F. = ·005594 pound. [Haswell, p. 215.]

1 cubic foot H at 14·3166 and 74°·68 weighs

$$\cdot005594 \times \frac{14\cdot316}{14\cdot7} \times \frac{492\cdot66}{535\cdot34} = \cdot0050133$$

1 cubic foot of gas weighs

CO_2, ...	4·02 ×	22 =	88·44
O, ...	·26 ×	16 =	4·16
CO, ...	25·38 ×	14 =	355·32
H, ...	4·51 ×	1 =	4·51
CH_4, ...	1·79 ×	8 =	14·32
N, ...	64·04 ×	14 =	896·56

1363·31 ; sp. grav. (H = 1) = 13·6331

Weight 1 cubic foot gas = ·0050133 × 13·6331 = ·06835 pounds.

Cubic feet gas used per explosion

$$= \frac{\cdot07938}{\cdot06835} = 1\cdot1614 \text{ cubic feet} = 2006\cdot90 \text{ cubic inches.}$$

Cubic feet occupied by air per explosion. Assuming that the composition of the air is 23 parts O and 77 parts N, its specific gravity is 14·46 as compared to H, and

1 cubic foot air = ·0050133 × 14·46 = ·72492 pounds.

Cubic feet of air used

$$= \frac{\cdot09963}{\cdot07249} = 1\cdot3744 \text{ cubic feet} = 2374\cdot96 \text{ cubic inches.}$$

Or the total volume of gas and air fed to the cylinder per explosion equals 2374·96 + 2006·90 = 4381·86 cubic inches.

As this charges all coal to engine, including leakage and that used for blowing off in the morning, this amount should be greater than that required to fill the cylinder at atmospheric pressure.

From cards the average volume filled at atmospheric pressure was approximately 4012·673 cubic inches.

WEIGHT OF MOISTURE IN GAS AND PER EXPLOSION.

Cubic inches, ... = 2006·9 = 1·1614 cubic feet.
Pressure, ... = ·4214 pounds per square inch.
Temperature, ... = 74°·68 F. = 23°·71 C.
One cubic metre, ... = 21·18 gramme [Kohlrausch, p. 229.]

$$35\cdot3161 \text{ cubic feet} = \frac{21\cdot18}{2\cdot205 \times 1{,}000} \text{ pounds.}$$

$$1\cdot1614 \text{ cubic feet} = \frac{21\cdot18 \times 1\cdot1614}{2\cdot205 \times 35\cdot3161} \text{ pounds} = \cdot0003159 \text{ pounds.}$$

ENTERED CYLINDER PER EXPLOSION.

	Weight.		*Pounds Gas.*		*Heat Units.*
CO_2, . . .	6·50	$\times \frac{\cdot 07938}{100} =$	·005159700		
O, . . .	0·23		·000182574		
CO, . . .	26·08		·020702304	× 4,328 =	89·60
H, . . .	·33		·000261954	× 62,032 =	16·25
CH_4, . .	1·05		·000833490	× 23,883 =	19·91
N, . . .	65·81		·052239978		
	100·00		·07938		
Moisture, ...			·0003159		
Air, . . .	126·64	$\times \frac{\cdot 07938}{100} =$	·100526832		
Total weight per explosion, .			·180222732		
Total heat per explosion, ...					125·76

DISCHARGED FROM CYLINDER PER EXPLOSION.

	Weight.		*Pounds Gas.*		
CO_2, . .	49·65	$\times \frac{\cdot 07938}{100} =$	·039412170		
O, . . .	5·18		·004111884		
CO, . . .	·49		·000388962	× ·4328 =	1·68
H_2O, . .	5·38		·004270644		
N, . . .	165·94		·131723172		
	226·64				
Moisture, ...			·000315900		
Total weight per explosion, .			·180222732		
Heat obtained from each explosion, ...					124·08

HEAT CARRIED OUT EXHAUST FOR 1° DIFFERENCE OF TEMPERATURE.

CO_2, ...	·0394	× ·2169*	=	·0085
O, ...	·0041	× ·2175	=	·0009
CO, ...	·0004	× ·2450	=	·0001
H_2O, ...	·0043	× ·4805	=	·0021
N, ...	·1317	× ·2438	=	·0321
Moisture, ...	·0003	× ·4805	=	·0001
				·0438

Difference between temperature of gas and of exhaust = 752·81 — 74·68 = 678°·13, and the heat accounted for in the exhaust per explosion = ·0438 × 678·13 + 4·46† = 34·16, and assuming that the exhaust for those times during which no explosion takes place, carries off the same amount of heat, we have

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* *Stewart's Heat*, p. 295.

† Heat of vaporization of H_2O.

$$34{\cdot}16 \times \frac{160{\cdot}145}{157{\cdot}57} = 34{\cdot}72$$

heat units accounted for in exhaust.

Heat carried away in jacket water, ... = 5988·5 B.T.U. per minute.

Heat carried away per explosion

$$= \frac{5988{\cdot}5}{157{\cdot}57} = 38{\cdot}005 \text{ B.T.U.}$$

Heat per explosion turned into power (indicated),

$$\frac{127{\cdot}7 \times 33{,}000}{157{\cdot}57 \times 778} = 34{,}375 \text{ B.T.U.}$$

Brake H.P. per explosion

$$= \frac{92{\cdot}49}{157{\cdot}57}$$

Heat units equivalents

$$= \frac{92{\cdot}49 \times 33{,}000}{157{\cdot}57 \times 778} = 24{\cdot}889 \text{ B.T.U.}$$

Heat in one pound coal, ... = 14117·818
Heat in equivalent gas, ... = 9756·79, eff. producer 69·1
Heat units available per explosion, = 125·76
Heat units used per explosion, . . = 124·08, eff. explosion 98·7
Heat units for exhaust, ... = 34·721
Heat units for jacket, ... = 38·005
Heat units for power, ... = 34·375
Heat units not accounted for, . . . 16·98
Heat turned into I.H.P., ... = 34·375, eff. of transformation 27·7
Heat turned into B.H.P., ... = 24·889, eff. of machine, 72·4
Eff. of plant, 69·1 × 98 7 × 27·7 × 72·4 = 13·66 per cent.

Coal used per I.H.P. per hour

$$= \frac{3{,}626 \times 60}{127{\cdot}7 \times 1788{\cdot}69} = \mathbf{{\cdot}9511}$$

Coal used per B.H.P. per hour

$$= \frac{3{,}626 \times 60}{92{\cdot}49 \times 1788{\cdot}69} = \mathbf{1{\cdot}315}$$

Combustible used per I.H.P. per hour = ·8729 × ·9511 = **·8302**
Combustible used per B.H.P. per hour = ·8729 × 1·315 = **1·148** +

A large part of the 16·98 heat units not accounted for is partly due to the fact that the pyrometer in the exhaust shows a temperature which is less than the true temperature of the gases because of the short time of the exhaust, and partly to the fact that all the gas from the coal is charged to the engine, whereas part of it was discharged in putting the producer into operation.

The low mechanical efficiency was partly due to the fact that the engine was new, as it had just been completed when it was tested.

The results obtained include all the fuel used during the three days of the test and are therefore a fair indication of the amount of fuel that would be used in actual practice.

RESISTANCE TO SHIP'S MOTION: A NATURAL LAW NEWLY DISCOVERED.

By F. M. F. Cazin.

[*Concluded from p. 310.*]

Vendors of mathematical apparatus have a tool called burette, which is a glass tube, the inner transverse section of which is one centimetre square, this is of a diameter as $\sqrt{4/\pi} = 1·1848$ centimetre.

Then there are marks on the tube beginning at the open end of the tube, the other end being closed by a stop-cock, and these marks are distant the first from the open edge, and one from another just one centimetre, which leaves the inside (volume) spaces between marks to each measure just one cubic centimetre. And of necessity the water contained in the tube between each set of successive marks measuring one cubic centimetre weighs one gramme.

Besides this burette there should be procured three more objects, viz: a solid cylinder of the precise section to fill the tube and when inserted therein to (easily) slide therein without allowing any water to pass between it and the inner wall of the tube, the cylinder being just one centimetre long and in consequence in volume just one cubic centimetre, and weighing just so many grammes as its specific gravity expresses. And it will do no harm to have two of these, viz: one of a density = 1, which will not sink in the water, and the other one of a higher density, and which in consequence will sink in water.

The fourth object wanted is a vessel deep enough to set the burette upright therein and leave some space above to spare. Otherwise this vessel may be of any width, if only room for water is left around the burette, and, for all we need care for, it might be a pond or the Atlantic Sea itself.

The burette being intended only to assist in judging of or measuring correctly the quantity of medium moving consequent to movement of solid, but not being intended to confine the movement of the medium to within its limits, a series of fine perforations are drilled through the wall of the burette, best on the division lines.

To repeat our experiment we should fasten the burette in an upright position inside the larger vessel, and fill the larger vessel and the burette with water to just level with the top-edge of the burette.

Having provided the described cylinder of higher specific gravity, which we may call "the ebony," with a silk thread to hold or withdraw it by, we should allow it to drop into the burette, filling the same in its transverse section, and we should cause this to take place so slowly, that we may clearly observe what is going on.

The observation will be materialy facilitated, if the water inside of the burette is colored but without increasing its density thereby, and to keep the colored water in the burette, until the free communication between the inside and outside parts of the medium at large is desirable or necessary. In order not to falsify the results, close rubber bands may be used for keeping the perforations through the wall of the burette closed, the removal of which bands from the circular lines of perforations will leave the communication between the inner and outer parts of the medium free.

We assume the upper line (ring) of perforations open, when the ebony is allowed to enter the top of the burette.

As the ebony begins to drop, the colored part of the medium contained so far in the burette passes out through the perforations, and outside of the burette a then visible ascending of parts of the water (medium) takes place to the surface, over which the ascending part at once spreads, until the equilibrium, which was disturbed by the additional volume of the ebony, is re-established.

If the ebony is allowed to drop only to the first mark, this is to remain with its top edge flush with the top edge of the burette, which was in the surface plain of the water, it will be found (the surface being proportionately within the limits of observation), that the surface has risen, just so and the same, as in the case of the steamer launched into a tank or limited harbor basin, where the rise might be also observed and measured.

If the mixing of the different parts of the medium be prevented by a cubic centimetre of oil occupying the upper cubic centimetre of the burette, it would become more clearly visible how the medium, displaced by the ebony, directly ascends to the surface and there spreads. But the critical observer would justly say, that the conditions thereby would lose the necessary similarity or identity, there being a natural tendency to arise to the surface in the oil, entirely independent of the movement of the solid. But there is yet the effect in this case also, which belongs exclusively to the immersing of the solid, viz: that the surface as a totality rises for the precise volume of the ebony.

And with all this the tendency created by lower density in the oil to move in the stated direction is not more powerful than the tendency created in the water pushed out of the way by the bow of the ship to flow continuously to *the* place, when the tendency to re-establish hydrostatic equilibrium dictates, where room is made equally continuously for it in identical quantity behind the ship's stern.

With the ebony occupying the upper cubic centimetre, there is an overflow over the upper edge of the burette and over the water surface in general. But with the ebony withdrawn, this overflow ceases and the original level of total surface is re-established inside and outside of the burette.

A hollow glass cylinder of the volume and form described for the ebony and of a density = 1 obtained, we may call it the "glass."

This glass will obtain its buoyancy, and being allowed to drop into the burette, as soon as its top face is level with the surface of the water. It is in consequence of this fact, that this glass, when left to sink by its own gravity, will not be overflowed, the same as the ebony was, consequent to the rising of the water, as soon as the lower edge reached the one-centimetre mark, but the upper edge of the glass will project just so far above the top edge of the burette as the surface of the water has risen above its former level.

And it will require the application of power (pressure, weight) to induce the glass to then further sink or fall in the medium, which is incontrovertible proof that there is some labor (mechanical) to be performed in causing the glass (solid) to proceed. If the ebony be substituted, this mechanical labor would be performed by the gravitation of the ebony. And this labor is the object of investigation, because it represents resistance overcome.

In order to establish the actual state of things, as it exists, when ships are floating on the sea, and to have things in a shape that medium moving be easily judged of as to quantity, I propose to then take one gramme or cubic centimetre of water out of the large vessel, which would leave the glass' top face in the same plain with the surface of the water.

With one of the cylinders occupying the upper cubic centimetre of the burette, we have undeniably the total medium with the one cubic centimetre of space within the outlines and limits, as they are set by hydrostatic equilibrium, with no part of the medium filling the space, where the solid glass or ebony is, which we can more readily understand, if we assume the total water (medium) temporarily frozen solid, and the solid cylinder (ebony, glass) removed to show the cavity.

With the second rubber band removed, we may then allow the ebony to proceed (fall) for the distance of one more centimetre (the distance of its own length, measured in the direction of motion *d*). Let us closely observe what is going on, while this movement takes place. Again we observe water (eventually oil) leaving the burette from just in front of the moving ebony.

When the ebony was started, there was a vacant space forming just above (behind) it, but a slight rising of surface taking place, an overflow into the burette at once followed, which filled the vacant space formed by the progress of the ebony within the burette.

With the tendency of motion created by continuous movement in the same direction, the same as by difference in gravity between water and oil, to rise, it would be observed that even the very same drops (molecules) pushed out of the way in front proceed to the rear of the ebony, which would be a truer representation of the actual occurrence under rapid (comparatively) progress (travel) than the slow motion with continuous impulse wanting.

With the ebony (solid) moved for the stated distance we then shall have the following state of affairs. Just one cubic centimetre of the medium (the value *B*, the solid's buoyancy, the volume of the medium equal to the solid's volume) has changed position, from what it occupied previous to the movement of the solid, and the change has been inverse of the direction in which the solid has moved. There has been an interchange of positions in equal volumes between solid and medium.

And with the travel for the second centimetre distance accomplished again, there would be observed a cavity filled with the solid where there was a quantity *B* of the medium before, but this same quantity would be again found in the place where the solid was, before it again moved the distance *d*. And this goes on at the same rate, as the solid advances, the gravitation of the ebony performing the labor of displacing in inverse direction to its fall the stated quantity of the medium. But, if we hold the tube horizontally in the same vessel, the ebony not gravitating, it would move only in the tube, if pushed, but moving it would cause the same movement of proportionate quantities of the medium in inverse direction to its own movement. The burette served in all this only to aid us in measuring the quantity of medium moving, the connection (with rubber bands removed) being open for the inside and outside parts of the medium to interchange their position, the same as if the tube were not there.

And, indeed, with our observation become keen to the actual state of affairs, we may now repeat the experiment without the burette and with the glass moving right close to the surface horizontally by our application of sufficient pressure for causing it to horizontally move. And in its movement it will truly represent the movement of the ship's immersed part in water at large. That there be more water does not vitiate the movement of its parts. In neither case can the solid proceed without *interchanging* position with measurable quantities of the medium.

THE FALSE THEORY OF EXCLUSIVELY LATERAL DISPLACEMENT.

And it is but proper, that I should show, that the theory of exclusively lateral displacement, as it has been opposed to displacement inverse to motion of solid, is not tenable, when critically examined. I prefer to do this by copying a few passages of my answer to the learned authors of this newest one of all dynamic theories.

The following lines are thus quoted :

" While my theory, based on experimental demonstration, leads to the absolute, ultimate and precise measurement of the effect of movement of the solid in submersion, your criticism culminates in your substituting for my precise equations your own attempt to explain the phenomena under consideration in a manner different from what I believe to have proven. And while you describe your own new theory, you advance no proof of any kind therefor, but claim in its favor self-evidence. Counter-criticism therefore is not applicable, and a simple denial of your unsupported claim alone is called for.

"As human knowlege has advanced, the claim of self-evidence has grown wonderfully less. Nothing is self-evident, that still leaves a reasonable doubt, and the rational doubt is fatal to the claim of self-evidence. And here is one reasonable doubt of many others. Unless you claim under the film claim also a contraction of water to a less volumetric quantity for the same weight, or unless you also claim that the re-establishment of hydrostatic equilibrium partake in the rapidity of lightning—the thickening of films must be visible on either side of a moving ship to the extent of about half the total immersed volume of the ship. And yet the ocean steamer equipped with the propeller screws at proper distance below the surface, and possessing a horizontal section closely adapted to the molecular division lines of the water, produces even at high speed almost no perceptible side-waves. But seamen's practice knows of propeller suction, this is of a velocity of the water next to the ship's sides far in excess of the velocity of the ship herself, this is of a velocity of the water in inverse direction to that in which the ship moves, as a consequence of both ship and water moving relatively in inverse directions.

"Your statement allows of no other conclusion than that displacement of medium has no part whatever in the resistance offered to motion of ship, but that friction, impact, inertia absorb the power that is required to cause movement of ship. While these are names for pretended values in resistance, neither you nor any other theorist or experimenter have stated precise values in kinetic equivalents of energy for these names. I have given real values of ideal precision and clearness. Their validity cannot properly be denied by claiming self-evidence for undefined presumed other values.

"If under your film theory the lateral displacement results, as it then not possibly could otherwise, in the lifting of water sideways above the general level to the full measure of the volume, for which room must be made, you must, in order to uphold the claim, that such continuous lifting of water compensates for itself, also claim that all of the water so raised presses, when on the surface, in no other direction but against the ship and in the direction of its travel. And this, gentlemen, is contrary to the actual facts, as they are known and daily observable.

"The new theorems, as I presented them for acknowledgment or criticism, have made precise distinction between displacement inversely to the solid's movements on the one hand and lateral displacement on the other, and for either the precise quantities of the medium so displaced have been stated, and proof has been rendered for each. It would have been according to good and respected precedent amongst scientists and with sound logic, gentlemen, if you had controverted these proofs, but you have controverted the conclusions only, and you have done this by advancing without any proof therefor a counter-claim on your part, for which you claim self-evidence, as if your claim were an axiom that humanity were unanimous about.

"It thus appears that you have never truly shown, what I do claim, to be a fallacy, nor the controverting claim you have advanced to be true."

CORRECT APPLICATION OF POWER FOR PRODUCING MOVEMENT OF SHIP.

From the theorems by me advanced, and as I claim also proven, the logical sequence can or must be drawn, that to produce progress of ship, a quantity of water $B/d\ v$ per second must be moved from bow to stern, this is: must be moved continuously in inverse direction to the ship's travel at the rate of $B/d\ .\ v$ kilogrammes per second, and if the power employed for removing this quantity of water is applied in a method and manner directing all force exclusively to the said purpose, then

$$\frac{1}{75}\cdot\frac{B}{d}\cdot v \times \frac{v^2}{2\,g} \text{ horse-power (metric)}$$

will be sufficient for producing progress of ship with the velocity v, if B is expressed in litres ($= 0{\cdot}1^3{}_{\mathrm{m}}$) or in kilogrammes.

I may illustrate this method of propulsion as follows:

If by some means or other there be created continuously in front of the ship's bow a vacuum, this is: if the water that is in front of the ship's bow were continuously removed, and if the impulse to fill up the vacuum, in which ship and surrounding water would equally participate, unless either the one or the other possessed such impulse in excess of the other, were increased for the ship, by pressing the same quantity of water, that is removed from in front of the ship's bow, in between the bulk of water and the ship's stern, thus doubling the impulse in the ship to fill the vacuum, as against such possessed by the surrounding water, must not from continuous action as thus specified result continuous progress of ship? And can it be otherwise than that the rate of progress would be proportionate to the quantity of water removed from bow to stern? And what indeed are paddle wheel and propeller screw actually doing in our daily experience?

Therefore continuous displacement of medium in inverse direction to the ship's (solid's) motion is not only the result of all movement in submersion (immersion) but also the most rational method for causing progress of ship.

And it is in the nature of things, that the quantity

$$= \frac{B}{d} . v$$

of water per second need not move in a volume, of which B/d is the transverse section, but that the higher velocity of motion in this water may make up proportionately for reduction in transverse section, and if it takes less power to move this quantity of water on a straight and direct line than on a circuit, then a more effective method of applying propelling power is indicated than the one now practised.

To guide the quantity $B/d.\ v$ of water per second in the most direct line possible from bow to stern, there should be a longitudinal tube, open to the water at both ends, and therefore not being part of the value B (buoyancy), through which tube the water ($B/d.\ v$ per second) should be caused to pass in inverse direction to that of the ship's intended travel. And the propeller screw or screws may be located inside of this longitudinal tube or tubes, and the motive-power may be applied to them, not in their centre but at their circumference. Thus may the most objectionable part of present construction, the cumbersome and unreliable propeller shaft be avoided, and the blades be better protected than they are in present construction. Even the possibility of dispensing with the steam engine entirely and of employing instead, steam jets, directly within such tube or tubes, for propelling the water in inverse direction to the ship's travel, is rationally deserving of serious consideration. And under provision for closing the tubes at their ends, they may be pumped empty, increase the ship's buoyancy, if needed, or the screw may be repaired in open sea. And with provision for giving a direction to the outflowing water at the ship's stern, this water may serve to steer the ship more effectively than it is done with the rudder.

If in addition to the marks for draught the ship's bottom would show marks also for the value B this is for the first displacement including load, the captain might well on the start calculate his speed with the power at his command. And the rating for racing or insurance cannot justly be accomplished, unless it be under consideration of the value B/d, as presented in each case.

For both navigation and nautical construction the following theorems, directly resulting from those already stated, are of importance:

(7) By obliquely advancing the ship increases the resistance to her progress at the precise inverse rate, as she shortens the distance between two perpendiculars on the direction of her motion, leaving the ship between them on the plain of the water's surface.

(8) For the same volume (B) of solid the resistance to motion by the medium increases and decreases at the precise but inverse rate of the solid's length (d) measured (for ships on the water line) in the direction of motion.

(9) By increasing the length of a solid intended to move in submersion (ship-bottom) for a stipulated volume (B), the resistance by the medium to the motion of such solid is decreased at the precise same rate, viz: as the value d increases.

It is by the fundamental fact of measuring resistance to motion of solid in a medium by quantity of medium displaced in inverse direction to the solid's motion, that it has also been possible to establish a universal value for maximal velocity of a solid's fall in a medium as follows:

Maximal velocity of fall in a medium

$$= \sqrt{\delta . d . 2g . \frac{\delta - 1}{\delta + 1}}$$

δ signifying the density of the moving body when compared with the same volume of the medium = 1.

It is thus that I succeeded in building a new system for understanding and for measuring the relation between the matter of stable volume and form, that moves within a fluid or liquid medium and the medium itself.

And a correct measurement of this relation has been effected by ascertaining the fact of movement of medium in inverse direction as the result of the movement of the solid within the medium, and by ascertaining the precise quantity of the medium so moved, which again represents the quantity of solid moving relative to a time unit also.

By mathematical evolution a natural fact observed and acertained has been used to establish natural laws not before known, that relate with equal force and applicability to astronomy, aëronautics, gunnery and even to the railroad train and the use of water-power, indeed to all dynamic relations, as they do to nautics and navigation, because no movement of matter does apparently exist, but it is the movement of matter within matter, within a material medium.

FROM MINE TO FURNACE.

By JOHN BIRKINBINE.
President of the American Institute of Mining Engineers.

[*A lecture delivered before the Franklin Institute, November 14, 1892.*]

[*Concluded from p. 270.*]

While it would be interesting to follow the details of some of the special features of the great producers, it is not practicable in the limited time to do more than call attention to some typical illustrations of mines of different character, or the means employed for their exploitation, and the instances have been selected more with the object of exhibiting prominent features, than as an attempt to cover various details of operation. They are offered to illustrate the peculiarities of mining the different characters of iron ore in various sections of the country.*

During the present year considerable interest has been attracted to the apparently large deposits of iron ore of a satisfactory character, which can be easily mined from what is known as the Mesabi Range, in Minnesota, and this locality is now passing through the developing stages, which have characterized the earlier history of other sections in the Lake Superior regions which have become producers of iron ore.

The pioneers penetrate the forest, generally "packing" their provisions and tools with them, erect a log cabin, and start the preliminary operations with pick, shovel and hand drill, supplemented by hand winch, bucket and pump. If an apparently satisfactory deposit is found, machinery soon takes the place of manual labor, and compressed air is early applied to these enterprises. The necessity of labor saving appliances demands the prompt application of such economies, and not only are power drills introduced in the early history of most of the mines, but diamond drills are among the implements which may be found at work in the heart of a forest or in the midst of swamps seeking to discover the subterranean secrets. In fact, one who has never visited a newly developing iron region, would be surprised to note how quickly the economies for exploring or exploiting mines, and for transporting the material from them are introduced.

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* The lecture was illustrated by numerous lantern slides.

Interesting lessons can be learned by visits to mines in different sections of the country, which are operated to produce the various classes of iron ores. The red hematite mines of the Minnesota Iron Company in Minnesota, the Norrie Mine, the Ashland, the Colby, of the Gogebic Range; the Lake Superior, the Cleveland, the Champion, the Ludington, the Florence and the Penn Iron Mining Company, in the Menominee Range, each possess some quality of interest to the investigator, either by the depth to which the deposit is wrought, sometimes to 1,300 feet; the extent of the underground drifts, the occurrence of ore in the lenses, and in some cases the admixture of magnetite and hematite, all offering interesting themes for study. The Nevada system of timbering, which is liberally employed in the Lake Superior mines, is also in strong contrast with the solid ore columns, 300 feet high, supporting the roof at the magnetite mines at Port Henry, N. Y., and similar though shorter columns at Lyon Mountain, N. Y., and other magnetic mines.

More contrasts are found in the open cut and underground work in different localities; the Tilly Foster mine of magnetite in New York State has become renowned for the efforts there made to secure its dangerous walls, commencing with great arches of brick, sustaining massive braces of concrete, which were placed in rooms which had been worked out, so as to permit removal of pillars, and ending with the blasting away of 500,000 tons of hanging-wall rock, so as to make the work an open cut. On the other hand, the Iron Mountain, Mo., originally wrought as an open cut, is principally exploited by underground workings to remove a mass of detrital ore from the original deposits which had been subsequently covered by rock of later deposition. The Cornwall ore hills have been wrought open cut until over 12,000,000 tons have been removed from them, an amount nearly four times as great as that won from Iron Mountain, Mo., and there are to-day magnificent faces of this soft magnetite exposed in the hills and railroad cuts passing through the Cornwall property. The mining of the carbonate ore deposits near the Hudson River, N. Y., the winning of the fossil ores in Northern New York, the stripping of sand from the bog deposits of Texas, the handling of the brown hematites of Alabama, Tennessee and other States by steam shovels, all add to the variety of methods and appliances used.

TRANSPORTATION OF IRON ORES AND COAL.

Much of the iron ore from the Lake Superior region, from New York, and some from other States, also large quantities of coal, have to be transported long distances to reach points of consumption, and reshipment is necessary where the transportations are made by both rail and water. An essential of such rehandling and transporting is that it should be done in the least possible time and at small expense, in order to enable the ores to compete with others, which, although not so rich, are found nearer the blast furnaces. As the principal cost of rehandling is for labor, large amounts of money have been expended by different iron and railroad companies for docks and cars built specially for the purpose, so as to bring this item to the lowest point practicable, and also make it possible to handle greater quantities of material than by manual labor. It is now no unusual thing for ore to be taken from the mine in "skips," automatically dumped into specially constructed railroad cars or into ore bins from which it can be discharged into cars, then hauled in these cars to ore docks, where the drop bottoms of the cars are opened and the ore falls into pockets, from which it is run into the hold of the vessel, and in this whole process the only labor necessary is to open the doors of the bins or the bottoms of the railroad cars.

The ore shipping docks on Lakes Superior and Michigan (the largest in the country, if not in the world), in connection with the ore receiving docks at the lower lake ports (fitted with bridge tramway plants), the railroad cars, and in some cases vessels specially constructed for this purpose, have aided materially in reducing the cost of transporting iron ore to points of consumption. The furnace manager, by means of advanced methods, cheaper or richer iron ores, improved facilities, and larger output, has lessened the cost of pig iron, which in turn has lowered the price of manufactured iron and steel, which has been one of the most important, if not the most important factor in bringing this country up to its present degree of prosperity.

In addition to the seventeen shipping docks erected to handle iron ores from the Lake Superior region, there are others of less magnitude on Lake Champlain, on the Mississippi River, and elsewhere, but the proportions of the docks on Lakes Superior and Michigan and the quantities of ore handled by them are much greater than the others, and the same holds true concerning the ore-receiving docks at lower lake ports, for from this region was obtained 52 per cent. of all the iron ore mined in the United States in 1891.

The ore-shipping docks consist of a wooden structure, built on piles. The top of the dock is from 38 feet to 51 feet 10 inches above the ordinary water level and wide enough to accommodate from two to five lines of railroad tracks. The ore docks have from fifty to 300 pockets, holding from eighty to 170 tons of ore each. The pockets are sheathed with plate iron and slope downward toward the water side of the dock. At the bottom of each pocket is a door which is controlled from the top of the dock. When it is desired to load a vessel, plate-iron chutes, usually semi-circular in form, are lowered into the hatches of the boat, the doors which connect these chutes to the respective pocket are raised, and the ore discharges itself into the hold of the vessel.

Marquette, Mich., is the port from which the first Lake Superior iron ore was sent, and up to the close of the year 1891 there have been loaded into vessels 17,616,880 tons at this port, which in 1891 ranked third, with a shipment of 1,056,027 long tons, all from the Marquette Range.

In 1865, Escanaba, Mich., claimed a share of the shipments from the Marquette Range, this port and Marquette keeping company until 1879, when Escanaba took a liberal lead, chiefly by reason of the development of the Menominee Range, commencing in 1877, and this lead has been continually maintained. In 1891, 3,058,590 long tons, or nearly one-half of the lake shipments, were sent from this port. Of this the Marquette Range contributed 1,154,645 long tons, the Menominee Range 1,480,248 tons, and the Gogebic Range the balance, 423,697 long tons. Since 1865 there has been handled at the Escanaba docks a total of 29,963,257 tons.

The following will indicate how rapidly ore is handled by these docks: One steamer was loaded with 1,659 long tons of iron ore in forty-five minutes; others with 3,027 long tons in three hours, 3,132 long tons in four hours, 2,379 long tons in two hours, 1,927 long tons in two hours, 2,502 long tons in two hours, 1,850 long tons in forty-five minutes. In this last case just one hour elapsed between the arrival of the boat at the dock and its departure. The record for most rapid loading is that of 980 tons, which were run into a steamer in four and three-quarter minutes. The maximum quantity handled at the Escanaba docks into vessels in twenty-four hours was 42,320 long tons

The nearly simultaneous development of the Gogebic iron range in Michigan and Wisconsin and the Vermilion iron range in Minnesota caused the erection of shipping docks, three for the former at Ashland, Wis., and two for the latter at Two Harbors, Minn., both ports making their first shipment in 1884. Ashland, however, soon outstripped its rival and in 1891 ranked second as a shipping port, with 1,261,658 long tons as its output. Since the docks were erected at Ashland in 1884, 7,760,025 tons of ore have been shipped.

In 1891, Two Harbors, Minn., ranked fourth, 890,299 long tons being shipped, and the total from 1884 to the close of 1891 was 4,030,899 long tons. Receiving docks are also projected at Duluth, Minn., to accommodate the anticipated increased shipments from the Mesabi Minnesota mines.

Gladstone, Mich., made its first shipment of ore in 1889, and serves as an additional and competing shipping point for the mines of the Menominee Range. In 1891, 177,866 long tons were shipped.

The length of the seventeen ore-shipping docks, independent of approaches, varies from 400 feet to 1,800 feet. The aggregate of all being 19,342 feet, or (say) three and two-thirds miles. They contain 3,189 pockets, have a total capacity of 385,350 long tons, and cost, approximately, $4,500,000.

In connection with these docks the railroad companies own a total of 12,526 cars, built for use in transporting iron ore, with an aggregate capacity of 187,550 tons of iron ore, their total cost being estimated at $3,600,000.

Six mining companies on Lake Superior own a total of thirty-three vessels, mostly steamships, with an aggregate tonnage of 80,750, especially devoted to the transportation of iron ore, and maintained by the iron-ore producers.

RECEIVING DOCKS.

The bulk of the lake shipments of iron ore are taken to the lower lake ports—Cleveland, Fairport, Ashtabula, Toledo, Sandusky, Huron, Conneaut and Lorain, O.; Erie, Pa., and Buffalo, N. Y., for distribution to the various blast furnaces in Pennsylvania, Ohio, West Virginia, New York, etc. The remaining portion going direct to furnaces situated near to or on the Great Lakes, such as Milwaukee, Wis.; Chicago, Ill.; Detroit, Mich.; Tonawanda, N. Y., and to individual furnaces at various points in Michigan and Wisconsin. Most of the furnaces on the lakes or their estuaries have special appliances for handling iron ore, but it is at the first-mentioned ports on Lake Erie that the larger receiving docks are located, Cleveland having four, Buffalo three, Ashtabula and Fairport two each, and the remaining ports one each.

Two of the receiving docks at Cleveland are each half a mile in length and have a storage width of 350 feet; one at Fairport has a water front of one mile and a width for storage purpose of from 180 to 350 feet. As the ore is stored in piles from twenty-five to fifty feet in height, the capacity of each of these docks is from 1,000,000 to 1,500,000 long tons, and the average storage capacity of the receiving docks is 300 to 500 tons per foot of water front. During the shipping season, from May to October, the ore is brought to these ports, unloaded, a portion being handled directly to railroad cars and the balance stocked, being shipped to the blast furnaces during the winter months. The largest stock on hand at lake ports in the past nine years was on December 1, 1890, when 3,893,487 long tons were on the docks. The largest stock of ore at the opening of navigation was that on May 1, 1891, when the heavy stocks of the previous year had been reduced to 2,662,223 tons.

Mr. George H. Ely, in a paper, entitled "The Great Lakes of North America,"* gives some some interesting figures in regard to the capital invested in iron ore mining and transportation in the Lake Superior region. The amount of capital invested in the iron ore lands, shipping and receiving docks and their equipment, in railroad cars, vessels, etc., was over $175,000,000.

CONCENTRATION OF IRON ORES.

Considerable interest has for several years been exhibited in the concentration of magnetic iron ores by means of magnetic separators. This is not a novelty, as the United States Patent Office has issued nearly 150 patents (some of them half a century old) for various forms of magnetic separators. The revival of interest in the concentration of lean magnetic iron ores is fortunately at a time when improvements in machinery for reducing in size and handling large quantities of material are supplemented by advanced knowledge of electro-magnetic appliances. The extent to which the process can be applied commercially to many ores, can be decided only after a thorough investigation, embracing the chemical and physical characteristics of the ore, the quantity accessible, the facilities for obtaining it, and the available market for concentrated ore.

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* International Congress on Inland Navigation. Paris, 1892.

This method of beneficiating iron ores is confined to magnetite, or possibly to some ores which can by roasting or other process be made sufficiently magnetic to permit of their concentration by the appliances mentioned. Most of the work done has been in enriching lean magnetite, although some ores carrying high percentages of iron have been fed to magnetic separators for the purpose of reducing the amount of phosphorus and sulphur. The predominance of magnetic iron ore in New York and New Jersey, and the existence of large deposits of this class of ore in Pennsylvania and North Carolina, have naturally attracted to these States most of the development in concentrating plants.

There is no question but what the amounts of sulphur, phosphorus, silica, and in some cases titanium, existing in magnetites can generally be considerably reduced if the material is sized and passed through magnetic separators; the degree of perfection reached being influenced by such reduction in size as will actually permit the mechanical separation of the pure magnetite from the other ingredients. In some of the titaniferous iron ores, this element is so combined as to be magnetic, and similarly the sulphur in other ores is in such combination as to make it partially magnetic. It may be possible with improved machinery and greater knowledge to separate various materials from each other, which differ but slightly in magnetism, but present practice is confined to separating magnetic from non-magnetic material, and the results achieved depend largely upon the comminution of the material, the rapidity with which it is fed on the separator and the perfection of the machine.

We may consider the term "concentrates" as applied only to ore which has been comminuted by means of crushing machinery and then passed through water-jigs or magnetic separators to remove materials which lower the grade of the ore.

In jigging, the crushed ore is agitated, water being introduced, which removes the lighter material, while the heavier iron ore sinks and is conveyed from the jig as it is separated. It is in this way that at Lyon Mountain, N. Y., the Chateaugay Ore and Iron Company treats the lean magnetite taken from the mines, and a similar method is followed at Iron Mountain, Mo., for the separation of the leaner red hematites.

Magnetic separators have been in use for forty years, but it is only lately that this system has attracted much attention. Although the forms of magnetic separators vary, they may be classed under three general heads:

(1) Altering the trajectory of falling material by introducing the attraction of a magnet, to draw the magnetic portion away from the non-magnetic. Six of this class of machines are now used.

(2) Feeding the ore to a revolving drum or drums, in which is a magnet core, the shells of the drum being either of alternate magnetic and non-magnetic strips, or entirely of magnetic or non-magnetic material. In some of these drums the magnet core is wound so as to exert a constant polarity, in others a series of magnets of alternate polarity compose the core, and in some opposite drums are of opposite polarity. When two drums are used, they are placed so as to revolve toward each other, the ore passing between them, or they are arranged tandem, the drums revolving in the same direction, but sometime at different speeds and with different degrees of magnetic force, so that the ore fed from one drum to the other receives successive treatment. Machines are also arranged with more than two drums. About thirty of this class are in use.

(3) Belt machines in which the ore is fed to a belt or series of belts passing under or over magnets or magnetic drums, the machines working sometimes in water and sometimes dry. In some of the machines the polarity is maintained continuously by means of pole pieces, in others the material is constantly submitted to magnets of alternate polarity, the belts being placed so as to run either vertically, horizontally, or on an incline, according as the conditions require. There are between twenty-five and thirty of this class now at work.

These separators are used either at the mines to enrich the ore, at steel works and rolling mills to remove the magnetic particles from slag and dirt, to separate iron ore from pottery clay or from emery—and in one instance iron ore occurring as a hematite with zinc ore is treated in a roasting furnace after being comminuted, and becoming magnetic, can be thus separated.

There is apparently a present field for magnetic separation in the States of New York, New Jersey, Pennsylvania, Virginia, North Carolina and Michigan, where there are large deposits of lean magnetic ores. The prejudice against the use of concentrated ore by some blast furnace managers has been largely overcome by practice, which has proven that properly concentrated ore contributes to the good working of the furnace, and in the future this class of ore may be used largely in place of some of the higher-priced ore brought to Eastern blast furnaces. This class of ore has also been used in most of the direct processes, and any development of these will encourage a corresponding demand for concentrates.

During the year 1891 there were produced 16,802 long tons of hand-picked or cobbed ore, 98,546 long tons of magnetically separated ore, and 110,777 long tons of jigged ore.

CONCLUSION.

In presenting for your consideration the subject of this evening, I have relied mainly upon the eye, believing that in this way it would be possible to convey more information concerning typical features in an attractive manner than to weary you with theories and detailed statistics. Most of the time has been devoted to iron ore, because nearly all that we use or import is smelted to produce pig iron, and but a portion of the coal mined or limestone quarried enters into the production of iron. But the small attention given the fuel and flux must not be considered as a gauge of their importance. The mining and quarrying, the preparation, the handling of the raw materials entering into the manufacture of pig iron supplies work for an army of laborers, miners, mechanics, railroad men, sailors, clerks, engineers, superintendents and managers, and demands the investment of many millions of capital.

OBITUARY.

EUGENE NUGENT.

EUGENE NUGENT, one of the oldest members of the Franklin Institute, died on February 28, 1893, at the Washington Hotel, Philadelphia, where he had resided for a number of years. While the deceased at no time took a prominent or active part in the affairs of the Institute, he was for years a regular attendant at its meetings and lectures, and a constant occupant of its reading-room, and his associates will miss his familiar figure from its accustomed place. Mr. Nugent was born in Germantown (Philadelphia) in the year 1805, and was engaged in various business pursuits in his native city and in Louisville, Ky., until about the year 1867, when he retired from active business. He was of an extremely retiring disposition, and his surviving business associates speak in the highest terms of his probity and scrupulous fidelity to duty.

The deceased never married. At his request, his body was cremated, and his ashes now rest in Laurel Hill Cemetery.

W.

PROCEEDINGS
OF THE
CHEMICAL SECTION
OF THE
FRANKLIN INSTITUTE.

[*Stated meeting, held Tuesday, April 18, 1892.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, April 18, 1892.

DR. WM. H. GREENE, President, in the chair.

The Section met at the usual hour. A number of bills, for subscriptions to journals and expenses incurred by the Actuary in mailing the Section's notices and papers, were approved for payment.

An interesting paper, by Dr. Edgar F. Smith and Mr. Vickers Oberholtzer, on "The Action of the Haloid Acids in Gas Form upon Molybdic Acid," was read by Dr. Smith, and was referred for publication.

Adjourned. H. PEMBERTON, JR., *Secretary pro tem.*

PROCEEDINGS

OF THE

ELECTRICAL SECTION

OF THE

FRANKLIN INSTITUTE.

[*Stated meeting, held Tuesday, March 28, 1893.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, March 28, 1893.

MR. E. G. WILLYOUNG, President, in the chair.

The stated meeting of the Section held on this date, was called to order by President Willyoung, at 8.10 P.M.

Present, thirty-four members and visitors.

The minutes of the previous meeting were read and approved.

The Treasurer reported a cash balance of $59.92 in the treasury, and presented bills for printing amounting to $35.51, which were ordered paid.

On behalf of the special committee appointed at the last meeting for the entertainment of members at this meeting, Mr. C. W. Pike stated that arrangements had been made for an informal lunch to be held at Reisser's restaurant, at the close of the evening's exercises.

Upon suggestion by Dr. Wahl, the Secretary was instructed to send a list of associate, corresponding and honorary members of the Section to the Actuary of the Institute.

Owing to an engagement, Prof. Houston's paper, on "Chas. A. Coulomb and his Work," was given first place on the programme.

It was an interesting memoir, and evoked quite a discussion concerning the correctness of some of Coulomb's discoveries, as viewed in the light of present knowledge.

The paper was referred for publication.

"The Migration of the Ions," by Prof. Geo. F. Stradling, was a *résumé* of researches by Hittorf and Kohlrausch on the velocity of various ions in solutions of varying degrees of density. This was followed by a paper by Mr. C. Billberg, on "A Simple Method for Increasing the Output of Dynamos and Motors." This method is to use iron for the binding wire of the armature instead of non-magnetic alloys.

Mr. Carl Hering pointed out the fact that Dobrowlsky made use of an iron ring inside the pole pieces, which diminished the sparking and allowed the shifting of the brushes to the position of greatest difference of potential, thus increasing the output.

Mr. Winand pointed out the distinction between Dobrowlsky's method and that of Mr. Billberg.

It was moved that further discussion on the papers of Prof. Stradling and Mr. Billberg be postponed till the next meeting, and that the papers be printed and sent out as soon as possible.

The meeting then adjourned. R. H. LAIRD, *Secretary.*

THE MIGRATION OF THE IONS.

BY GEORGE FLOWERS STRADLING.

[*Read at the stated meeting of the Electrical Section, March 28, 1893.*]

For almost a century the passage of an electric current through an electrolyte has been attributed to direct transportation of the electricity by the ions resulting from the decomposition brought about by the current. The changes and improvements imparted to the crude theory of Grotthuss by Williamson and Clausius, and more recently by Svante Arrhenius, have not altered this explanation. Upon the startling, yet apparently correct, theory of Arrhenius, the reasoning which will subsequently be used might be based; but, as Grotthuss' simpler hypothesis lends itself more readily to explanation, it will be employed.

Suppose we are electrolyzing a dilute solution of sulphuric acid. The hydrogen goes with the current and appears at the kathode; the radical SO_4 moves against the current, and, but for secondary action, would appear at the anode. Each ion moves through the liquid, but with what velocity? Shall it be assumed that the velocity is the same for both ions? One thing that will go far toward determining the velocity is the friction of the moving atoms against their environment. As the hydrogen atom makes its way toward the kathode, it will come in contact with other hydrogen atoms and with the liquid in which the acid is dissolved, perhaps also with SO_4 groups moving in the opposite direction. The same thing is true of the other ion. Now, the two ions are, of course, quite different in nature, and the resistance which they will experience will, in general, be different. Hence, in general, their velocities will be different.

So much for the antecedent probabilities of the case. In order to put this reasoning to the test, it will be necessary to deduce results that must follow were the velocities the same, and others which must follow, if they are different, and then, by experiment, to determine which deductions are supported by facts.

Let the diagrams (*Fig. 1*) represent in a general way electrolysis upon the supposition that the ions move with equal velocities in opposite directions. *AB* represents an imaginary partition, so situated in the liquid that any changes in concentration arising at the electrodes will not affect the electrolyte in its vicinity. The positive and negative ions, united in the molecules of the substance being electrolyzed, are represented by circles having + and — signs, respectively. *Diagram I* represents the position of the ions before the passage of the current. In *Diagram II*, the current has passed long enough to move each positive ion to the left and each negative one to the right, through an equal distance, that distance being just enough to cause the liberation at the electrodes of one atom of each ion. In *Diagram III*, two atoms of each ion are set free, and two molecules of the electrolytic substance have been broken up.

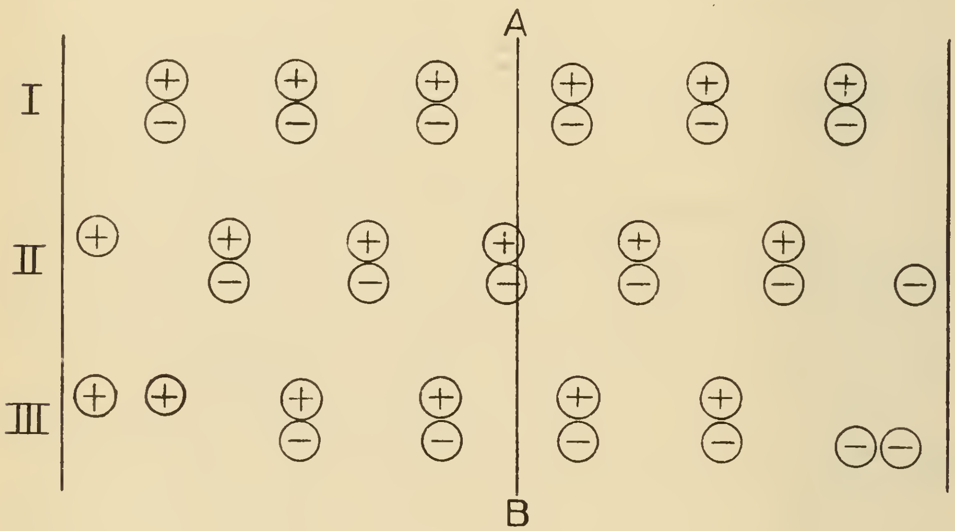

FIG. 1.

In *I*, there were three positive and three negative atoms on each side of the partition *AB*. In *III*, to the left of *AB* there are four positive atoms, and to the right four negative ones. Thus the gain of positive atoms to the left equals the gain of negative ones to the right. If now the entire quantity of the positive ion to the left of *AB* be found, including both the amount in the liquid and that set free at the kathode, and the gain over the amount present before the passage of the current be compared with the amount liberated at the kathode, the ratio is seen to be one-half, which is the same for the negative ion to the right of *AB*. The determination of the amount of the two ions present in the liquid can be made by chemical analysis, and thus

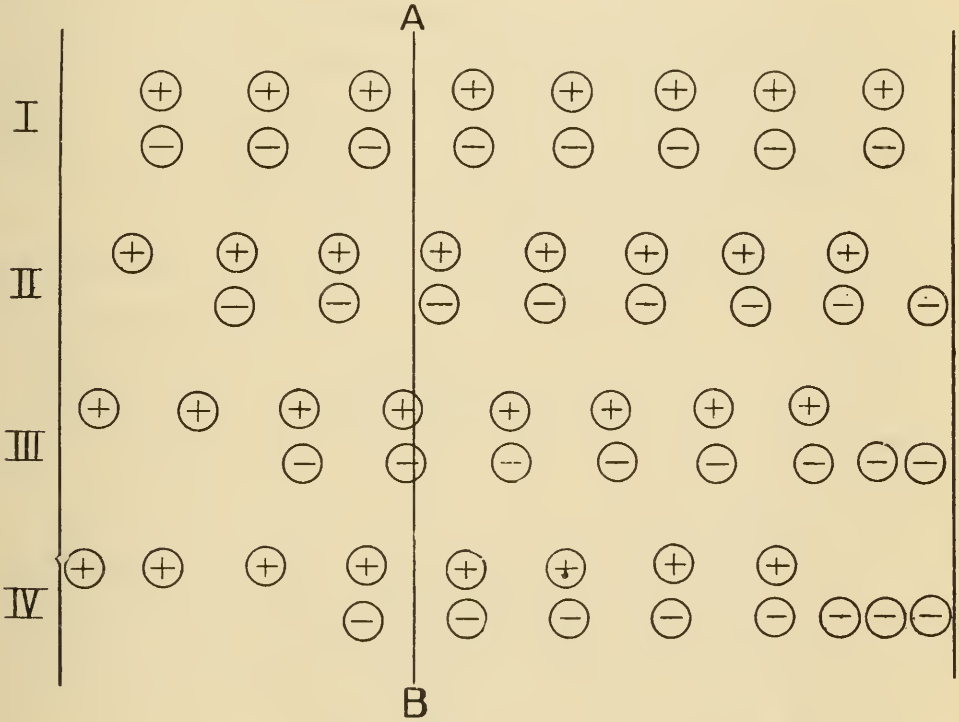

FIG. 2.

the tenability of the supposition of equal velocities be examined. If it is found that to the left of *AB* there is, after the passage of a current, a gain of the positive ion equal to one-half of the quantity set free at the kathode, and that the ratio holds true for the negative ion also, then, and only then, will it be shown that the ions have equal velocities.

In *Fig. 2* the positive ion moves to the left with but half the velocity with which the negative one moves to the right. *AB* has the same meaning as before; *I* represents the conditions before the passage of the current; *II*, *III* and *IV* show the state after the electrolysis of one, two and three molecules. Before the passage of the current, there are three positive atoms to the left and five to the right of *AB*, and, of course, the same number of negative ones. After three molecules have been dissociated, we find four positive atoms to the left and seven negative ones to the right; a gain of one positive atom and of two negative atoms on the respective sides. It will be noticed that the gains are as 1 : 2, in the same ratio as the velocities. A little consideration will show that, in every case, no matter what the ratio of the velocities is, this will hold true. In general, if the velocities of anion and kation are as $p:q$, for every p anion atoms that cross *AB* in one direction, q kation atoms cross in the opposite direction; and, since the gain of each ion is produced by the transference from one side of *AB* to the other, the gains are as the velocities.

A knowledge of the number of positive and negative atoms in each of the two portions of liquid separated by the partition *AB* would render it possible to decide whether the ions do move with unequal velocities. Though chemical analysis gives no knowledge of the absolute number of the atoms, yet it will give with certainty the relation of the gains of kation and anion, and this is sufficient. Take the case where the velocities are unequal, and, as above represented, in the ratio 1 : 2. Three molecules are dissociated. Three positive atoms appear at the kathode, and, to the left of the partition, one more such atom is present than before the passage of the current. The gain is, therefore, one-third of the quantity set free. Two negative atoms are gained on the right side, two-thirds of the quantity set free. If, then, we know how much of the positive ion is present to the left of the partition at the beginning of the experiment, how much at the end, and how much is liberated or deposited at the kathode, the velocity of the positive ion is proportional to the amount gained divided by the amount liberated or deposited. In getting the amount present after the passage of the current, both that in the liquid and that set free at the kathode are to be taken into account.

The same procedure carried out for the anion, of course, gives a fraction to which its velocity is proportional, and the sum of this fraction and that obtained for the kation is unity. It is manifestly not necessary to carry out the analysis for both ions, for, having found one fraction, the other is found by subtracting the first from unity. For instance, if it is found that the gain of the kation to the left of the partition is two grammes, and the amount liberated is five grammes, then the velocity of the kation is as two-fifths, and the velocity of the anion as $1 - \frac{2}{5}$ or $\frac{3}{5}$. The velocities are here as $\frac{2}{5} : \frac{3}{5}$ or 2 : 3.

Hittorf* applied the reasoning which has been given to the determination of the velocities of a good number of ions. To collect the liquid on one side of an imaginary partition for analysis is no easy matter, but he succeeded in doing this with great skill, and obtained results which show a remarkable agreement with each other.

The following is an example of how the relative velocities were found for $CuSO_4$.

	Grammes.
Quantity of Cu liberated at kathode, ...	·3161
Decrease of Cu in solution on kathode side, ...	·2288
Net gain of Cu, ...	·0873
Ratio of gain to deposit, ... $\frac{873}{3161}$	= ·276

Hence, vel. of Cu : vel. of SO_4 : : 276 : 724.

A table of Hittorf's results is to be found in vol ii, *Wiedemann's Electricität*, from which those below are taken:

Substance.	*H_2O to 1 Gramme. Substance.*	VELOCITIES. *Kation.*	*Anion.*
NaCl, ...	3·47	·352	·648
	20·70	·366	·634
	104·76	·372	·628
	320·33	·383	·617
Na_2SO_4, ...	11·77	·359	·641
$NaNO_3$, ...	2·99	·400	·600
KCl, ...	4·84	·484	·516
K_2SO_4, ...	11·84	·500	·500
KNO_3, ...	4·62	·521	·479
HCl, ...	2·90	·661	·339

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* *Vide Pogg. Ann.*, lxxxix, xcviii, ciii, civ and cvi.

Two changes might affect the relation of the velocity of the kation to that of the anion alteration of current strength and of concentration. Both were investigated by Hittorf. He found that the relative velocities are independent of the current strength.

For a solution of $CuSO_4$;

Intensity of Current.	*Velocity of Kation.*
113	·291
420	·285
958	·289

On the other hand, concentration does have a very decided influence. An instance of this may be seen in the case of NaCl, in the table given above. For $CuSO_4$ the following results were obtained:

	Velocity of Cu.
One part $CuSO_4$ to 6·35 H_2O.	·276
9·56	·288
18·08	·325
39·67	·355
76·88	·349
148·3	·362

There is, however, no reason to suppose that, in general, the effect of dilution would be to increase the velocity of the kation rather than that of the anion.

For twenty years after the publication of Hittorf's results upon the relative velocities of the ions, so far as the writer knows, no one made use of them in any way to get the absolute velocities. This was left for Friedrich Kohlrausch to accomplish.*

Think now of an atom of an ion moving in a dilute solution. Its friction is chiefly against the solvent, and but little against the other constituent of the salt in solution. It will then probably make but little difference what that other constituent is. The atom will probably move with a velocity not at all dependent upon the other atom from which it has been separated. In other words, it seems likely that in dilute solutions each ion moves with a velocity peculiar to itself and to the solvent, and not depending upon the salt from which it has come. Kohlrausch drew from his wide-reaching observations on the conductivity of dilute solutions data which show that such is really the case.

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* *Wied. Ann.*, vi, 160.

Suppose we have a portion of an electrolyte one centimetre long and one square centimetre in cross-section. Let its conductivity be k, the velocity of the kation be u, and of the anion v.

Let the cubic centimetre contain as much of the salt to be electrolyzed as would be formed by the union of that quantity of the positive ion which will convey m units of positive electricity to the kathode with the amount of the negative ion which will carry the same amount of negative electricity to the anode. One volt electro-motive force will be supposed to exist between the ends of the liquid column.

By Ohm's law—

$$C = \frac{E}{R} = E \cdot K, \text{ or as } E = 1, C = K. \qquad (1)$$

It is also possible to express the current strength in terms of u and v. There are m units of positive electricity moving toward the kathode with the velocity u, and an equal quantity of negative moving in the opposite direction with the velocity v. This is equivalent to m units of positive electricity moving to the kathode with the velocity $u + v$. In one second, then, $m\ (u + v)$ units of positive electricity would pass through any cross-section of the liquid column, and this is accordingly another expression for the current strength.

$$C = m\ (u + v) \qquad (2)$$

From (1) and (2) we get

$$K = m\ (u + v) \qquad (3)$$

From his experiments, Kohlrausch found the quantity by which m must be multiplied in order to get the conductivity. By comparison with (3) it is seen that this quantity must equal the sum of u and v. From Hittorf we get the ratios of u and v, and from Kohlrausch their sum, and from the two relations the absolute values of u and v are readily obtained.

The following results, in which numbers proportional to u and v are given, show how near to the truth is the supposition that the velocity of an ion in a dilute solution is independent of the salt from which it is separated:

	From Chloride.	*Iodide.*	*Nitrate.*	*Acetate.*
K,	$u = 48$	51	46	47
Na,	$u = 31$	34	29	31
	Cl.	*I.*	NO_3.	$C_2H_3O_2$.
From potassium salts,	$v = 50$	52	45	23
sodium salts,	$v = 51$	51	46	23

In the table which follows, in addition to the absolute velocities of the ions, there is given the force in gravitation units which must act upon one milligramme of the ion to give it a velocity of one millimetre per second. These forces are very large, but Kohlrausch shows that they are of the same order of magnitude as the forces necessary to overcome the friction between such exceedingly small portions of matter as atoms (in which the ratio of surface to mass is very great) and the liquid solvent. The velocities are those which would be produced in a column of liquid one millimetre long, with a difference of potential of one volt at the ends.

Ion.	Vel. mm. per sec.	Kgm.	Ion.	Vel. mm. per sec.	Kgm.
With Monobasic Acids.			CN,	·054	7,000
			NO_3,	·049	3,200
			ClO_3,	·043	2,700
H,	·300	32,500	$C_2H_3O_2$,	·025	6,700
K,	·052	4,800			
NH_4,	·050	10,800	*With Dibasic Acids.*		
Na,	·034	12,500			
Li,	·022	61,600	H_2,	·179	54,500
Ag,	·043	2,100	K_2,	·043	5,800
Cl,	·053	5,200	$(NH_4)_2$,	·039	13,700
Br,	·057	2,100	Na_2,	·024	17,800
I,	·057	1,300	Li_2,	·012	113,000
Fl,	·032	16,000	Ag_2,	·034	2,600
½ Ba,	·031	4,500	SO_4,	·043	4,700
½ Sr,	·030	7,300	CO_3,	·039	8,300
½ Ca,	·023	17,700			
½ Mg,	·025	33,000	*With* SO_4.		
½ Zn,	·022	13,900			
½ Cu,	·031	9,800	Mg,	·015	54,000
			Zn,	·013	23,000
			Cu,	·013	24,000
			SO_4,	·024	8,600

When the solution is not dilute, the question of friction becomes a more complicated one, and the ratios of *u* and *v* change with the concentration.

m.	*u.*	*v.*	
0	·179	·043	for H_2SO_4.
1	·166	·034	
2	·153	·031	
4	·125	·027	
8	·071	·022	

Oliver Lodge has actually observed the velocity of the passage of hydrogen. It moved through a tube filled with sodium chloride dissolved in jelly, decolorizing phenolphthalein as it went. He found the velocity to be ·29 millimetres per second, whereas the calculation of Kohlrausch gave the closely agreeing result ·30.

In November of 1892, J. J. Thomson brought before the Royal Society an account of experiments conducted by Mr. W. C. Dampier Whetham upon the velocity of certain ions. A current was sent through a tube containing $CuCl_2$ and NH_4Cl. The boundary was distinct and its rate of motion could be accurately measured.

	Observed.	*Calculated.*
Vel. of Cu,	·0309	·031
Cl,	·057	·053
Cr_2O_7,	·047	·0473

It is seen by a comparison of observation with calculation that they lead to almost identical conclusions respecting the absolute velocities of the ions. It is therefore safe to assume that the suppositions which underlie the calculated results are in the main correct.

NORTHEAST MANUAL TRAINING
HIGH SCHOOL, PHILADELPHIA.

SOME PRINCIPLES THAT MUST BE OBSERVED IN ORDER TO MAKE A GOOD CLOSED-CIRCUIT BATTERY, AND A NEW PORTABLE DRY CELL DESCRIBED IN WHICH THESE PRINCIPLES ARE APPLIED.

BY E. F. NORTHRUP.

[*A paper read before the Electrical Section, Dec. 28, 1892; Jan. 24, 1893.*]

[*Concluded from p. 323.*]

Some careful tests were made of the life of different cells, usually by determining the total number of coulombs that they could furnish. This test was conducted by running the cells connected in series through a copper voltameter until they were completely exhausted. Some resistance was usually placed in the circuit to prevent too rapid action. The life of a Barrett silver chloride cell tested in this way proved to be 2,473 coulombs or nearly $\frac{68}{100}$ of an ampère hour. The average total current supplied by one of the smallest size iodine cells described above (see *Fig. 1*), in which the depolarizer was sulphur iodide, was ·21 of an ampère hour. This, considering the small size of the cell, is a very high efficiency and it might be increased somewhat if desired by using a larger proportion of the depolarizer. The iodine and mercury oxide depolarizer gives even a higher efficiency than this. A similar test was made upon a larger size iodine cell, which had a volume of 1·1 cubic inch, and the form slightly modified, as shown in *Figs. 2* and *3*. This furnished 2,295 coulombs or ·64 of an ampère hour. As these cells are only intended for test work very little current is taken from them. Assuming that the average resistance used in the entire circuit of a resistance set is 1,000 ohms, and that forty volts are used and that the duration of each closure of the key is one second, 17,500 taps would be required to exhaust one of the smallest cells and 57,375 to exhaust one of the larger ones. Thus for the purpose to which these cells are adapted their life is very long.

Of course, this same combination of materials might be used in cells of various forms and any size. A cell, constructed as shown in *Fig. 2*, which is $\frac{5}{8}$ x $2\frac{1}{2}$ inches, will have under thirty ohms internal resistance and will furnish through fourteen ohms external resistence about thirty to forty milliampères; so this style of cell may also be used with advantage where current rather than electro-motive force is

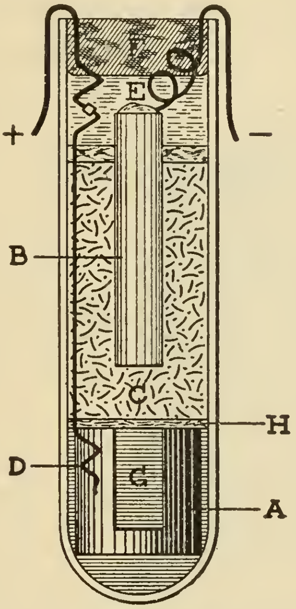


FIG. 2.—Large iodine test cell.

A = carbon electrode shown in perspective in *Fig. 3*.
B = zinc electrode.
C = paste, same as in other cells.
D = platinum fine wire.
E = viscous seal.
F = plaster Paris seal.
G = depolorizer, either I_2S_2 or $HgO + I$.
H = partition of asbestos cloth.

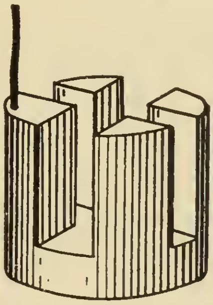


FIG. 3.—Perspective view of carbon electrode used in larger form of test cell.

required. Other forms, however, were devised for this purpose. *Fig. 4* shows a cell with a square case, $1\frac{1}{8}$ x $2\frac{3}{4}$ inches, which is especially adapted for running physicians' induction coils. The depolarizer, which may be either I_2S_2 or $HgO + I$, is placed in the partitions of a box-like carbon

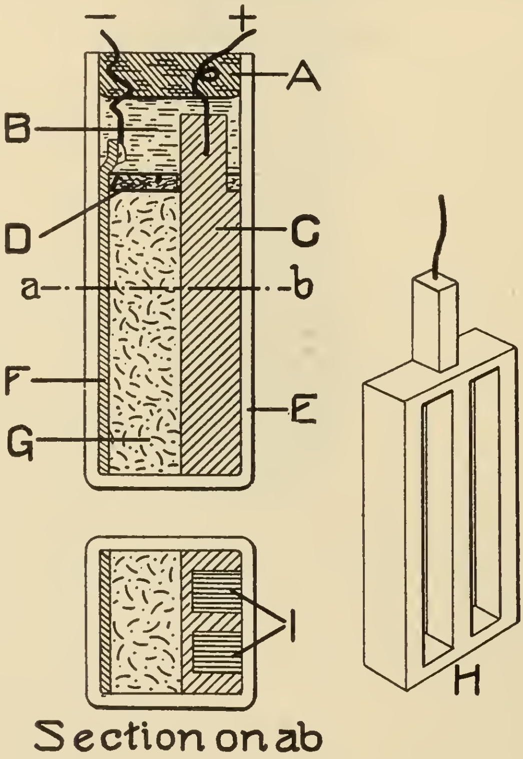


FIG. 4.—Iodine cell adapted for large current output.

A = plaster Paris or cement seal.
B = viscous seal.
C = carbon electrode (view of edge).
D = cork to hold electrodes in place.
E = containing case of glass.
F = zinc electrode (view of edge).
G = paste (same as in test cells).
H = perspective view of porous carbon electrode.
I = depolarizer, either I_2S_2 or $HgO + I$.

electrode, the open side of which is placed against the side of the glass case. The carbon electrode is thus seen to serve also the purpose of a porous cup. This general principle of having the depolarizer behind or inside of a porous carbon electrode, so that the current does not have to pass through a substance of high resistance, is one which seems capable of valuable developments. Experiments are now being continued along this line aiming towards the construction of a large powerful battery for cautery work, running of motors and other purposes where great efficiency combined with transportability is required, and it is hoped that results will soon be forthcoming.

Some very exhaustive experiments were made, using free bromine for a depolarizer. But this in an unmixed or uncombined state had to be finally abandoned, as the bromine diffused through the electrolyte and caused the cell, whether kept on open or closed circuit, to give out in about a month. The device was finally adopted of dissolving the bromine in carbon disulphide. This practically prevents diffusion of the bromine, but does not seem to affect its qualities as a depolarizer when used with a porous carbon electrode like the one described and shown in *Fig. 3*. The combination gives about 1·8 volts. It is hoped that these cells are free from defects, but the important test of time must be given to them before this can be positively asserted.

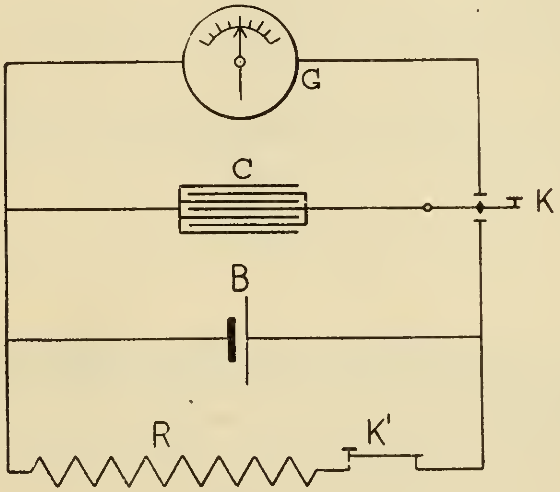
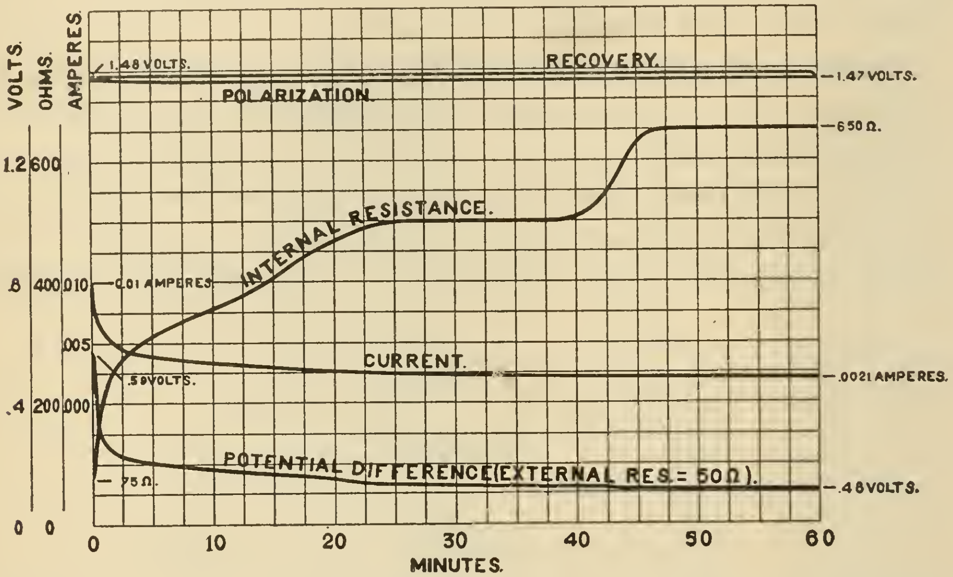


Fig. 5.

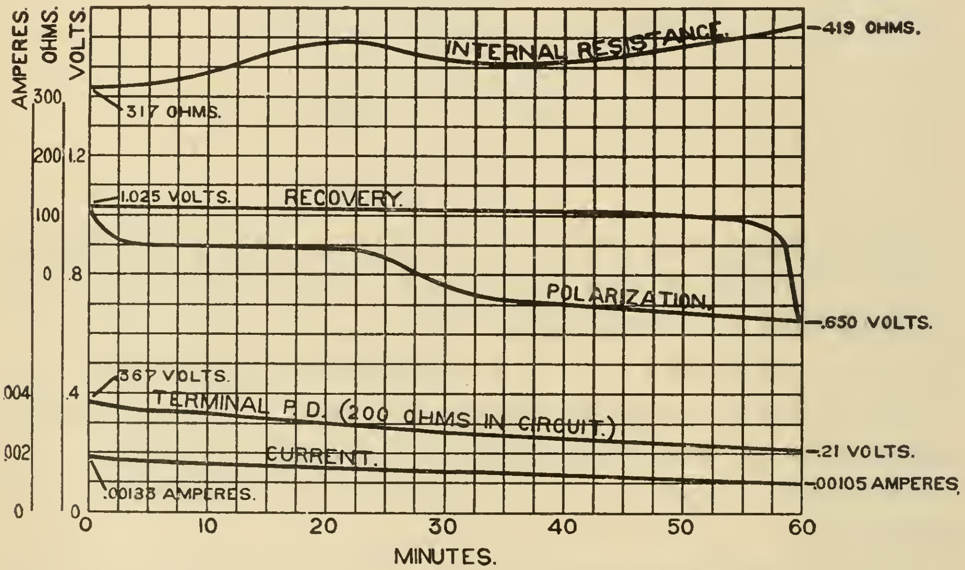
The complete record of the action of a battery is given by curves which represent their polarization, recovery, internal resistance, terminal potential difference and current. The method adopted for obtaining these curves is fully described in Prof. H. S. Carhart's work on primary batteries.

It may be called the condenser method and briefly stated is as follows:

In the diagram, *Fig. 5*, *G* is a ballistic galvanometer, *C* a condenser, *B* a cell, *R* a resistance, the fall of potential over



CURVES NO. 1.—Curves of a Zn / $MgCl_2$ / Hg_2SO_4 / Hg cell. Size, 2 x ¾ ins.



CURVES NO. 2.—Curves of a Zn / $ZnCl_2$ / CuO / Cu cell.

which is to be measured; *K′* a key to put this resistance in circuit with the battery *B*, and *K* a double key for charging the condenser and discharging it through the galvanometer.

The condenser is first charged (K' being open) by means of a Carhart-Clark standard cell, then discharged and the galvanometer deflection read by means of a telescope and scale. The standard is then replaced by the battery to be tested. With K' open, the condenser is charged and discharged as before. Then K' is closed and after an interval of one minute the condenser is again charged and discharged. K' is now kept closed for an hour, except at intervals of two minutes, when it is opened just long enough to charge and discharge the condenser, and readings are taken which give the potential of the cell on open circuit. The condenser is also charged and discharged, K' being kept closed, at intervals alternating with the open circuit readings. At the end of the hour K' is opened permanently and open circuit readings are taken at intervals of one minute or longer. In this way the recovery curve is obtained.

The deflection of the standard and its electro-motive force being known, the electro-motive forces corresponding to the other deflections are calculated from a simple proportion or more easily read off from a straight line curve, which is readily drawn.

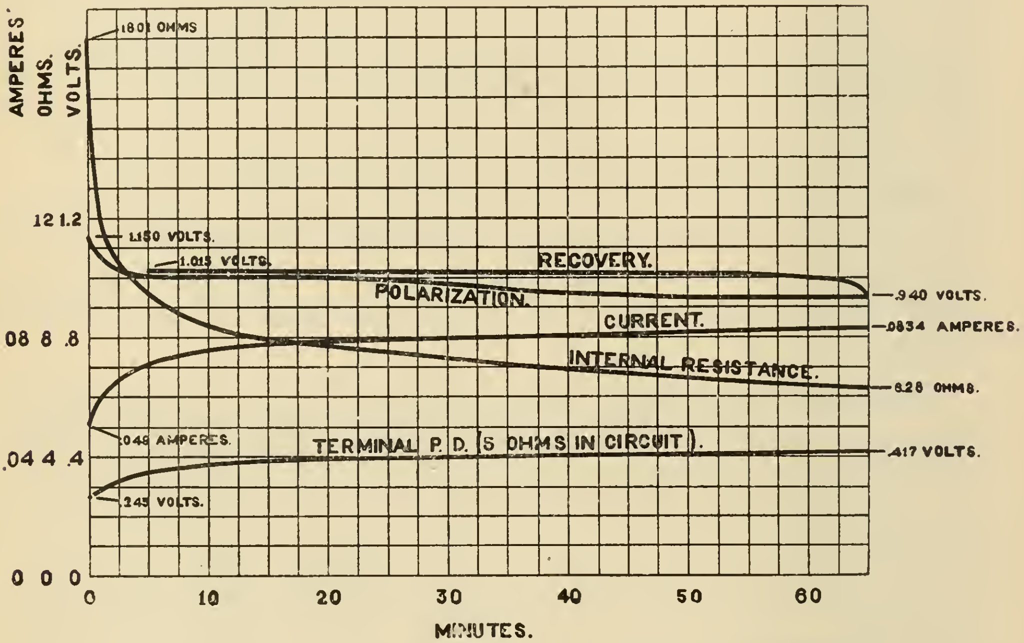
The internal resistance of the cell at any moment during the hour is obtained as follows: Call the electro-motive force of the open circuit readings at any moment E; that of the closed circuit reading at the same moment, which is the fall of the potential over the resistance, R, E', then, if r is the internal resistance sought, we can make the following equations: There is a total potential of E, there is a fall of potential over the external resistance E'. Therefore, there must be a fall of potenial $E - E'$ over the internal resistance, hence $r : R :: E - E' : E$ or

$$r = \frac{E - E'}{E'} R$$

After the polarization curve given by the different electromotive forces called E, and the terminal potential difference curve given by the electro-motive forces called E' are plotted, then the data for solving the equations giving the points for the internal resistance curves can be read off on the ordinates directly. The current flowing at any time is, simply,

$$C = \frac{E'}{R}$$

If in addition to this test a battery is run completely out through a voltameter, and the number of coulombs that it will furnish be calculated, and, if further, after being used some it is laid away for a few months to test if any destructive local action goes on, then, if all these tests are favorable, the battery may be pronounced a good one, and not with certainty before.

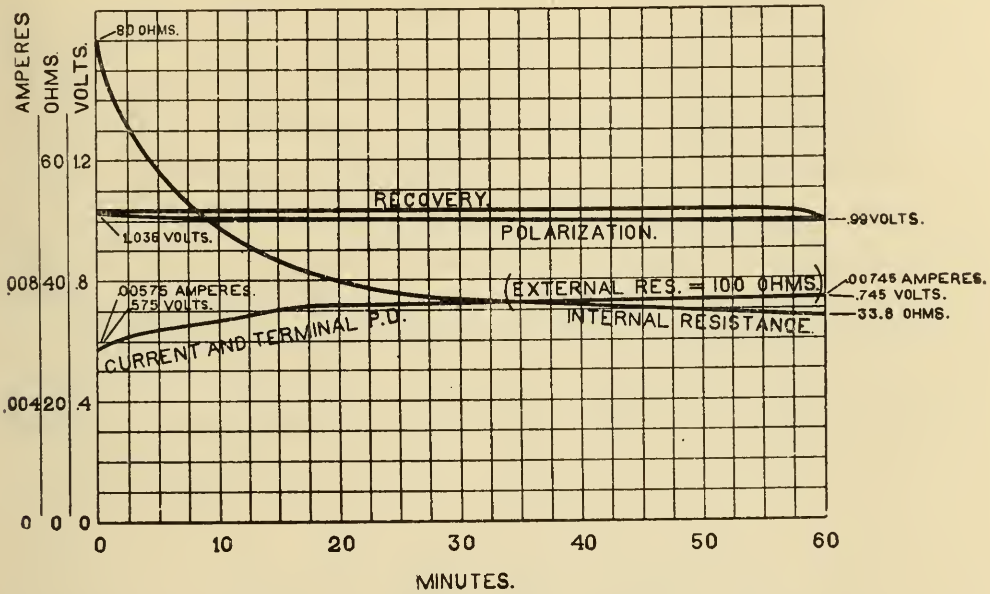


CURVES No. 3.—Curves of the Barrett silver chloride cell.

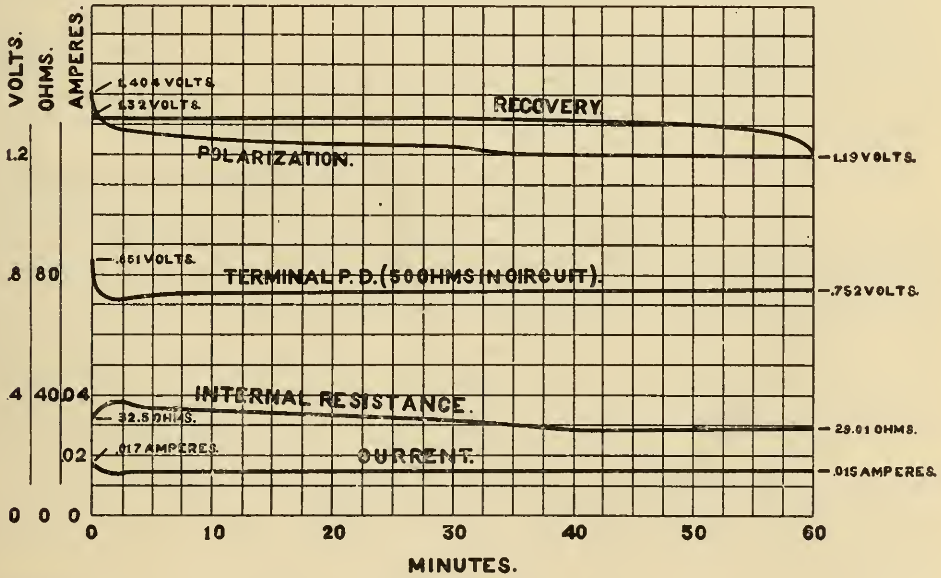
There are very few of the "wonderful" dry cells advertised which will bear such an exposure as the above tests will give them, and unless the manufacturers of cells claimed to be perfection are willing to submit their goods to such tests their honesty will at least bear examination.

The following curves of some dry cells made by various parties and characteristic of different types of depolarizers are given for reference. These cells do not differ much in size from the iodine cell shown in *Fig. 2*:

Curves No. 1 represent the action of a $Zn / MgCl_2 / Hg_2 SO_4 / Hg$ cell constructed upon the same general plan as the iodine cell in *Fig. 2.* The Hg_2SO_4 is a solid depolarizer and the cell has a very high resistance, which runs up rapidly. The electro-motive force of this combination is the highest



CURVES No. 4.—Curves of the Stevenson silver chloride cell, same size as Barrett cell. Size of cell itself without protecting case is 2⅝ x ¾ inches.



CURVES No. 5.—Curves of small iodine test cell. Size, 2 x ½ inches. Depolarizer, sulphur iodide (I_2S_2).

that can be obtained in a closed cell in which a metal is used for the negative electrode, which is depolarized by a salt that is reduced to this metal, unless use be made of the rarer elements. Curves No. 2 are those of a cell with CuO for a depolarizer and a paste made of red oxide of iron. These cells also are valueless on account of their high resistance. They have also, considering the small amount of current taken from them, polarized very rapidly. Curves No. 3 are those of a Barrett silver chloride cell. The resistance of these cells rapidly falls as the silver chloride of poor conductivity becomes reduced to spongy silver of the very best conductivity. The faults of this cell, such as gassing and local action, are not shown by the curves, but it is seen that the electro-motive force is on an average only a little above nine-tenths of a volt. The curves of this cell, nevertheless, are very fine, for silver chloride contains a large percentage of the most active depolarizing element, combined with the best known conductor. The cost of silver chloride, however, is a strong objection to its use. Curves No. 4 are those of a Stevenson silver chloride cell. The resistance of this cell is greater than that of the Barrett cell, but it has polarized less. The low resistance of the Barrett is due to the fact that the poorly conducting silver chloride is wrapped about with a fine silver wire. The Stevenson cell does not have this wire, which results in a higher resistance, but having no free silver surface the polarization is less.

Curves No. 5 are those of a small iodine cell, only 2 x $\frac{1}{2}$ inches, with a depolarizer of I_2S_2. The resistance, it will be observed, decreases, though at the start it is far within the limits allowable for a test cell. The electro-motive force is also seen to drop. This is due to the exhaustion of the nearly insoluble iodine from the end of the carbon prong, but the recovery is very prompt, so that for testing work, where only a little current is taken at a time, the available electromotive force will be that shown by the end of the recovery curve.

For purposes where much steady current is required the size and form of these cells will be like that indicated in *Fig. 4*. Curves of this latter form have not yet been obtained, but several tests have been made by running them completely out on a milliampère meter and upon induction coils which have proved their very high efficiency. With HgO united to I their available electro-motive force is about 1·4 volts and their internal resistance between one and three ohms, and their total output greater than the silver chloride cells described.

The battery problem is not an electrical one merely. It is chiefly a chemical and mechanical question and one which a person with only an electrical knowledge can scarcely hope to undertake with success. There are many improvements yet to be made in primary cells, and those who take the work up should bear in mind that a good battery, like anything that is at all complicated, cannot be stumbled upon, but must be laboriously and logically studied out, and then proved by careful experimenting to be of sterling value.

Franklin Institute

[*Proceedings of the stated meeting, held Wednesday, April 19, 1893.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, April 19, 1893

JOSEPH M. WILSON, President, in the chair.

Present, seventy-eight members and fourteen visitors.

Additions to membership since last report, eight.

The Secretary reported the resignation of Mr. John Hall from membership in the Committee on Science and the Arts. The resignation was accepted, and the meeting proceeded to fill this vacancy and the two others held over from the previous month, by election.

The result of the vote was the election of Mr. C. L. Prince for the unexpired term of Mr. Pistor; Mr. Henry Brinton for the unexpired term of Mr. McAllister; Mr. W. N. Jennings for the unexpired term of Mr. Hall.

Mr. John Hartman exhibited a series of handsome lantern views, representing the most notable specimens of ancient Egyptian architecture, and made some critical observations and comments upon their architectural and mechanical features. (To be published in abstract.)

Mr. George F. Simonds, of Fitchburg, Mass., read a paper on the manufacture of anti-friction ball-bearings, describing a system and apparatus which he had invented for this purpose. The speaker illustrated the subject by the exhibition of a number of specimens, large and small, provided with his improved journal bearings. He also showed examples of hardened steel spheres of $\frac{1}{32}''$ and $\frac{1}{64}''$ diameter, claimed to vary from perfect spheres by less than the $\frac{1}{1000}$ of an inch; and a collapsing mandrel devised by himself and used in his method of insuring absolute uniformity in the dimensions of the hardened sleeves employed in the production of his improved bearings. (Mr. Simonds' paper is referred for publication.)

Mr. James G. Satterthwait read a paper, briefly reviewing the history and development of the applications of electricity for heating purposes, and at the close of the meeting exhibited and showed in operation a large number of domestic heating appliances, of the Carpenter type, offered for inspection by Messrs. Walker & Keppler, of Philadelphia.

The Secretary read an official communication from Mr. S. Lloyd Wiegand, Trustee of the Elliott Cresson Medal Fund, notifying the Institute of the fact that a vacancy existed in the trust by reason of the resignation of Mr. Samuel Sartain, as a trustee, and, that in accordance with the terms of the deed of trust, the said vacancy must be filled by election, at the next succeeding stated meeting of the Institute after the receipt of this notice.

A communication from a special committee of the American Philosophical Society was presented, announcing the fact that "the Society will celebrate the one hundred and fiftieth anniversary of its foundation by a series of reunions at the Hall of the Society, during the week beginning Monday, May 22, 1893, terminating on Friday, May 26, 1893, at which papers may be offered by title by such delegates as may honor the Society with their presence." The communication concluded with the statement that the Society will be pleased to receive a delegate from the Institute.

The President was authorized by vote to name a delegate to participate in the proposed reunions.

A communication was presented from "The Committee of Fifty for a New Philadelphia," asking the Institute to appoint three delegates to represent the Institute in a "Union Committee," to be composed of delegates from the various organizations of citizens interested in public work, with the object of promoting needful municipal improvements. The President was authorized to name three delegates to represent the Institute in the committee, in the manner requested.

The meeting then adjourned. WM. H. WAHL,
Secretary.

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THE SCIENTIFIC EXPERT IN FORENSIC PROCEDURE.

BY PROF. CHAS. F. HIMES, PH.D.

[*A lecture delivered before the Franklin Institute, February 10, 1893.*]

The lecturer was introduced by the Secretary of the Institute, and spoke as follows:

MEMBERS OF THE INSTITUTE, LADIES AND GENTLEMEN:

The position and character of the representative of science in our courts of justice, always one of the greatest interest to those most directly affected, is acquiring every day a more general interest as the enterprise of the daily newspapers spreads before the public, often with comment, full reports of trials, in which, with increasing frequency, he often has a conspicuous part. A few years ago the appointment of a committee of the American Association for the Advancement of Science was suggested to consider the whole subject, but no report appears among its proceedings. Among the announcements of congresses at the coming Columbian Exposition, is one of Medical Jurists. As members of the medical profession were the first formally recognized as scientific experts by imperial decree, and as they have broken the way by the rulings and precedents established, for other classes of scientific experts, it may seem fitting that they should continue to lead, but in view of the growing importance and peculiar features of science in this regard, it is almost a matter of regret that the subject for consideration of such a conference had not been made Forensic Science instead of Forensic Medicine, especially since the presence of experts of different nationalities, and under different systems of jurisprudence might have added much to the interest and value of the deliberations.

The more immediate suggestion of the subject for the lecture of this evening is due to a lecture upon the same subject by an eminent jurist of the State to the students of the law school of the institution with which I happen to be connected. Whilst, with all the freedom of the lecture platform, it abounded in instructive suggestions of the highest practical utility, originating largely in his own experience, and whilst it was courteous and even fair to the expert, it still had much of the coloring that the opinions of most of his profession of the expert have, and which at times finds expression from the bench as well as from the bar, and finds its way into reports and text-books, and which, in the case alluded to, seemed to make the burden of advice to the young lawyer—to watch carefully the scientific expert. As illustrative of this coloring, the following extracts have been collated from a great mass, not altogether at random, but as exhibiting different points of view, and the most salient points of animadversion upon the expert. They will serve, in a measure, to direct the discussion of the subject.

In *Taylor on Evidence* we find: "Perhaps the testimony which least deserves credit with a jury is that of skilled witnesses. It is often surprising to see with what facility, and to what an extent their views can be made to correspond with the wishes or the interests of the parties who call them." "They do not, indeed, wilfully misrepresent what they think, but their judgment becomes so warped by regarding the subject in one point of view, that, even when conscientiously disposed they are incapable of expressing a candid opinion. To adopt the opinion of Lord Campbell they come with such bias upon their minds to support the cause in which they are embarked, that hardly any weight should be given to their evidence." A judge in a patent case, in his charge to a jury, says: "In a case of this kind the opinions of witnesses who are experts are admitted, contrary to the general rule, which requires witnesses to testify only to facts. And I must say, gentlemen, so far as my experience extends, that it would be as well if not better that the opinions of such witnesses should be excluded from the consideration of the jury." "They are selected on account of their ability to express a favorable opinion, which, there is great reason to believe, is in many instances the result alone of employment, and the bias arising out of it." In another charge to a jury we find: "It must be painfully evident to every practitioner, that these witnesses are generally adroit advocates of the theory upon which the party calling them relies. Even men of the highest character and integrity are apt to be prejudiced in favor of the party by whom they are employed." As to the effect of testimony of experts it is described, "as often as skilful and effective in producing obscurity as in elucidating truth." Again, a judge off the bench, in the greater freedom of a lecture, remarks: "From the proposition that experts alone may give their opinions upon the witness stand, that these opinions are admitted as such, and that the expert is to form and express his private conclusion upon the facts which the jury is summoned to try, from these propositions, it is but a short step to the full-blown expert, as we see him in actual operation, as one who being neither judge, nor juror, nor witness, nor advocate, exercises the privileges of them all, restrained by the limitations of none." Another very clear writer upon this subject, makes the following statements: "Text-books and reports, when discussing what may be termed the testimony of experts, more accurately than expert testimony, will be frequently found to censure, and seldom to commend its practical administration; and, indeed, the unprofessional mind, in view of the general tenor of the expression of the authorities, finds it difficult to understand, why a system which would seem to be regarded as rather pernicious than beneficial, should be even tolerated by the law;" and, in another connection, "an examination, even though superficial, of the subject of skilled evidence, from whatever point of view it may be made, will not fail to indicate the liability in the operation of the system, to misapplication and perversion of its functions, though administered under rules which have been well considered, and enforced with a reasonable degree of strictness;" "though the law theoretically provides so high a standard of qualifications for the expert as might be presumed to insure his sufficient skill, and further enables his ignorance to be indicated, or his errors refuted, by cross-examination and controverting testimony, yet the inability of men in general to investigate without assistance the questions which the expert deals with, embarrasses the process of detecting his unfitness in the first instance, and of counteracting the obscurity or false impressions produced by his testimony if erroneous;" "the salient objection which presents itself in the application of skilled evidence, and one which is of necessity peculiar to the system, is the effort frequently made, with more or less success, to expand and pervert the functions of an expert * * * to the statement or discussion of questions of moral or municipal law." This arises, however, as he admits, from the circumstance that: "Law and fact in a certain class of cases [viz: patent cases], are frequently so closely blended that it may be difficult to clearly draw the line between them, and to determine where the province of the witness ends and that of the court begins." Another phase of objection is exhibited by Justice Miller, in a charge, as follows: "My own experience, both in local courts and in the Supreme Court of the United States, is, that when the matter in contest involves an immense sum in value, there is no difficulty in introducing any amount of expert testimony on either side." Another judge, in a lecture upon "Medical Expertism," gives a similar opinion, that the grounds of dissatisfaction in regard to medical testimony, to both the professions of law and medicine, are "reducible to one, that upon every conceivable issue expert opinions are procurable, which sustain or seem to sustain the most contradictory views." These extracts, which might be multiplied indefinitely, exhibit a rather pessimistic view of the scientific expert, and one which, in our opinion, is hardly justified by a full consideration of all the facts, and which certainly is not just, in as far as it may imply censure of him, when we consider his relation to the system of jurisprudence, into which he has been thrust with little more responsibility on his part than he has for being born.

The scientific expert is simply a product, and an extreme product, of an advanced and rapidly advancing civilization. He was recognized in the germ, to be sure, by the old Roman law, and we may assume in all systems of jurisprudence; but he has acquired an immensely increased importance, and a much wider field and a far greater frequency of employment by the recent, and very recent, marvellous advances in the applications of science—applications which have increased the sphere of things to be litigated about, which have introduced facts of an entirely new character to be adjudicated upon, to say nothing of the contribution that science has made, and is continually making, in many ordinary cases, of conclusive missing links of evidence which render decision previously uncertain, comfortably certain, and satisfactory.

Now, one fact that seems latent in these expressions of the legal profession in regard to the scientific expert, and almost the first that impresses is that in many respects he seems to be a positive annoyance to lawyers, and even to judges at times—a sort of intractable, incompatible, inharmonious factor, disturbing the otherwise smooth current of legal procedure; too important or necessary to be ruled out, too intelligent and disciplined mentally to yield without reason to ordinary rules and regulations of the court, with which he may not be familiar, and, at the same time, possessing an undoubted influence with a jury, that it is difficult to restrict by the established rules and maxims of legal procedure.

Indeed it would seem that no class connected with the administration of justice is more frequently misunderstood, or abused, unless, perhaps, we may except the legal fraternity itself, for the latter are often, by the laity, accused of bold mendacity, unscrupulous methods, dishonest practices. And they sometimes even contribute to this popular impression by contradiction, or even abuse, and apparent mistrust of each other, even to a greater degree than scientific experts. And yet no one would hold the noble profession of the law less a necessity in the administration of justice, or consider it fairly represented by cases that may be regarded, if they exist at all, as glaring exceptions, pictures all the more grotesque for the background of professional character upon which they are cast. Now, there must be some way of accounting for such a community of reputation of lawyer and expert, widely separated as they are in position and function. The one has the advantage of a well-defined, clearly comprehended legal status, the result of centuries of judicial procedure; he is a growth, influenced by all the changing demands of progress in social conditions for centuries. Though there may not have been a time, when he was not in the germ, and always important, the attorney is now a fully developed agent in judicial procedure. The scientific expert, on the other hand, occupies an ill-defined, hardly recognized, variously comprehended, anomalous position, and of comparatively recent importance. He is, in fact, a comparatively recent introduction into the world of jurisprudence. He is in process of development and adaptation to his surroundings. He is being shaped and fashioned rather than finally fixed, and much of the misapprehension of him, and consequent abuse of him, may be due to his apparent, or real, want of compatibility with the fixed forms and maxims of jurisprudence which have the force of axioms in legal practice. Still the two professions, although thus widely dissimilar, must have some similar phases that may account in some degree for identity of reputation alluded to. Both are engaged in the trials of causes between litigants, and litigants in most cases fully persuaded of their rights. The lawyer and the expert, each in his sphere, contributes to the final decision. The memory of litigants is apt to be more tenacious of wrongs done than of rights secured. The rights are his, as a matter of course, and the lawyer, or expert, who has aided in securing them has but performed a simple duty, and may be regarded as fully paid, perhaps over-paid, by the fee. But the defeated litigant is apt to remember longer the opposing attorney, as a man, perhaps, of feeble sense of justice, of great cunning, perhaps of great legal ability, but mainly as the chief instrument in defrauding him of his just rights, and the expert, if one be associated in the case, shares this unfavorable opinion. The lawyer's opinion of an expert may rest upon somewhat similar grounds. The expert, who at a critical point may have saved a doubtful case, may be regarded by the lawyer as having performed a simple, perhaps an imperative duty; whilst the one who may have caused the loss of a case, or foiled an attorney, will be apt to be remembered by him as well as by his client, as a typical scientific expert, briefly characterized in the address to the court. "May it please the court there are three kinds of liars—the common liar, the damned liar and the scientific expert."

Another occasion of ill-feeling between the two professions may lie in the ill-defined position of the expert in court. In legal procedure there are hazy, doubtful zones, where the rules of practice are difficult of application, in which, as has been said, the scientific expert appears as playing all parts, with the restrictions of none; and yet, as we will see, he is classified by his functions with those who are regarded rather as inferiors by attorneys—namely. the witness class, and there may be a sort of *ne sutor ultra crepidam* feeling toward him on the part of the attorney, when he seems to rise above his class.

But aside from these rather incidental and comparatively trivial circumstances, there must be others of more comprehensive and graver character, which shape the reputation of the scientific expert with the bar, the bench, and to some extent with the laity, in as far as it does not filter down to the latter from the two former. In looking for these a multitude of questions almost jostle each other. What is the scientific expert? Why is he in court at all with all his failings? When did he get in? How did he get in? What are his relations to the other factors in the administration of justice, to the court, to the attorney, to the jury, to the other witnesses, to the parties in the case, to the community of which he forms a part, to civil law, to ethical laws, to his own profession, and then, the final, all-important practical question. What is the best thing to be done with him? If we restrict our inquiry to the jury system, most of these questions will meet their answers in a study of the growth of that system from the simple juridical germ, latent in archaic customs that with the effect of law regulated to some degree the rule of the stronger in the interest of the community. Thus primarily the avenger of a private wrong knew no limit to his revenge except his own will and power. All progress in jurisprudence rested upon increased assumption of control over individual conduct in accordance with the social instincts of the race. The prescribed rule of civil conduct for the individual was always becoming more detailed in its commands of what society considered right, and of prohibitions of what it considered wrong, and society was always incurring increased responsibility for the determination of facts, of conduct, and application of the rules. Elaborate systems of jurisprudence grew up. Our savage legal ancestors were late in evolving a system. Long before they had placed any restraint upon the right of the stronger, the Mosaic code had made the great advance in its restraint, which we might almost term the equitable basis of all modern law, of "an eye for an eye, and a tooth for a tooth." But late as the English system is its origin is lost in obscurity. The often-quoted figure of Sir Matthew Hale, "more undiscoverable than the sources of the Nile," although it may have lost its applicability, has not lost its expressiveness. But whether it is based on Anglo-Saxon usages, or whether almost wholly upon those of later date matters little. It is certainly a growth, a product of the creative power of the nation working slowly, and with evidences permeating it of the unquenched and unconquerable Anglo-Saxon spirit even under the grinding oppression of the Conquest.

Now in the organic world progress, development is from simple to more complex, by a process of differentiation. Low in the scale we find the animal without organs, without mouth, without stomach, without respiratory organs, without organs of sense; no eyes, no ears. A portion of food floats against it, it is enclosed and digested; the air is absorbed through its whole surface; the light may affect the whole surface; it is all mouth, all stomach, all lungs, perhaps all eyes. Any part performs all functions. It is regarded as low down in the scale of animal life. As we ascend the scale we find portions of the body set apart for specific functions by a process of differentiation. Organs of digestion, of respiration, of locomotion, organs of sense, eyes affected only by light, ears affected only by undulations of the air, all clearly defined, and as they perform their several functions, doing best only that which they are set apart to do, until we reach the culmination of development in highly differentiated and complex mammalian type. Thus the English system, by a process very analogous to differentiation, gradual, at times tedious and perhaps imperceptible, influenced by social and political changes, by the general progress in civilization, and following the same law that greater perfection demands greater complexity, to-day exhibits a sharply defined, legally constituted, fourfold division of juridical functions to four as clearly defined specialized organs of jurisprudence, each regarded as as incompetent to perform the functions of the other, as the eye to perform the functions of the ear, or the ear to perform those of the eye. We may not be able to trace the successive stages of development very clearly. What we regard as trial by jury in the Magna Charta may resemble it only in its faintest outlines, as indeed it may resemble other systems in many of its features. It may possibly hardly suggest our present jury system. But it had in it what has developed into that system, until the witness, the jury, the judge and the advocate constitute the ideal court of to-day. Whatever else may be uncertain, the respective functions of these are not, and nothing is regarded as more essential in the administration of justice than that their distinct characters should be preserved. And yet the development of the system has been, as we have said, in the separation of the functions of these, combined primarily, to a greater or less degree, in the same individual or in the same body. Thus, originally the juryman was the witness as well as a judge of the facts; and long after jurymen were made judges of facts as given by others in evidence, the juryman still retained the function of witness, still was free to consider facts of his own knowledge in making up his verdict, as well as those received in evidence. To-day, a fact of his own knowledge is no fact at all to a juror in making up his verdict, except as it comes to him from himself as a witness on the witness stand. Again, so rigidly is a witness required to refrain from any assumption of the functions of the jury, that, whilst he may in a case for damages to land give his estimate of the value of the land before the damage at $5,000, and his estimate of $1,000 after the damage, he would be restrained from estimating the damage at $4,000, because it is for the jury to make the subtraction. This illustration, which is from an actual case, will serve to emphasize the present condition of minute differentiation of functions of the system, into which system, as it is at present, the scientific expert is to be fitted. Now he is, if not an entirely new introduction, at least but recently developed, as we have already intimated, by the intense and peculiar mental activity along lines hardly known to the ancient Greeks and Romans, any more than to our own savage legal ancestors, and coming in contact at multitudinous points with the individual and society. But the system of jurisprudence has lost, we might say, in plasticity by growth. With forms at first scarcely fixed and limited in number, it grew with the requirements of expanding social conditions and material progress, it readily yielded to new demands upon it. But it has gradually become more rigid with fuller growth, until to-day it is strained by any effort or demand to accommodate it to the rapid progress of the race in very recent years beyond the conditions that shaped it.

As the scientific expert is classed, in the division made, as a witness, amenable to the same rules, without any discriminating marks, privileges or functions, a somewhat fuller consideration of this class may assist to a better comprehension of his status in the system.

Facts form the basis of judicial determinations. Their discovery and establishment form the fundamental part of judicial processes in all systems of jurisprudence. What is truth? is the first and all-important inquiry, or, as Bacon has put it, evidence is the lantern of justice. Here human testimony must always be the sole reliance. "All evidence rests upon our faith in it," with the latent fallibility of the senses, with the varying and undisciplined powers of observation, and with the perhaps still feebler power of statement and description, and withal with its liability to personal bias from interest or predjudice, or to sluggish indifference where these may be wanting. Many have been the expedients in all ages to enlarge or supplement human testimony, to test and purify it, to eliminate evident sources of error; and yet after all has been done by the best rules of evidence that large experience, combined with highest intellectual culture, could devise, there has always been, and always will be, that felt residue of doubt and uncertainty, which renders decision unsatisfactory or impossible, and which it should be the first concern of every system of jurisprudence to diminish. The highly cultured Greeks and Romans, to go back no further, skilled in dialectics, in all the arts that belong to judicial processes, resorted to the torture of witnesses to purify their testimony or to elicit fuller truth. Their great lawyers, to be sure, doubted its efficacy, and yet it remained, and in the nations adopting the Roman law grew into a still more complete, and almost diabolical system of procedure, even gaining an entrance into England in spite of its want of harmony with the Common Law, or rather with the Anglo-Saxon character. The instruments of torture exhibited in the Tower of London are almost necessary to convince us on that point.

Where such agencies, which we might call natural, were not employed, the superhuman was called in; the Deity himself was called, or forced, into court. The old Germans thought their gods too just to suffer wrong to be done if in some way they could be made responsible for it; and the same feeling was represented in England before the Conquest, by the various forms of ordeal devised. The test of walking over nine red-hot ploughshares without harm, of thrusting the arm into boiling water, of enforced presence of the suspected murderer before the victim, that at his touch the wounds might flow afresh, and many similar devices are the expression of a felt helplessness in dealing with human testimony. After the Conquest, these forms were simply superseded by other modes of appeal to Deity, in the Wager of Battle, which remained law, though not practised, even down into this century. These are but a few of the devices to get at truth, or to shift the responsibility for failure; and, it must be remembered, that they are the desperate expedients, not of savage, or even of pagan nations alone. To-day, with the entire ruling out of the supernatural, we are in a condition to consider the question of rendering purely human testimony as reliable and complete as it can be made. Possibly, yet, the oath, as it is ordinarily administered, with its adjuration taken from the Roman law, may, in some cases, have the effect of an appeal to a superstitious regard for a conventional form of lie, supposed and intended to be, more offensive to Deity than a simple, solemn, deliberate "yea" or "nay." But in most cases I think it can be assumed that the fear of human punishment for perjury is uppermost. With this acknowledged reliance then on human testimony alone, the rules governing its employment have grown into a completer system, and it is under these rules alone that the scientific expert can come into court, and he must be made to harmonize with them, even if the value of his testimony, by no fault of his, is to be seriously impaired. Let us see then where he gains an entrance under these rules. There is the first broad rule that testimony can relate only to facts; that inferences from facts are for the jury alone, as illustrated in the extreme application before given of the question of damages. There is the other equally broad and fundamental rule, applicable in all systems of jurisprudence, that the best evidence the case affords is to be given. But the ideal case of facts by the witnesses and inferences by the jury alone is difficult of complete realization. Facts and impressions from them often shade off so imperceptibly into each other, that they are not separable from each other in the minds of the witness, and there arises an apparent incompatibility in practice between these two rules; there occur cases in which too rigidly to exclude inferences by the witness would be to exclude the best evidence. A ready illustration is furnished by the question of identity. The impression, or belief on the part of a witness that an individual before him is the same that was seen by him at another time and place, may have the highest degree of certainty in his mind, whilst the facts upon which he bases it cannot be given in their entirety to the jury. He may exhaust his memory and his descriptive powers and yet there may remain a residue of facts, minute, inexpressible, inexplicable to the jury, more potent, perhaps, in forming his opinion than all that he could give. Legal practice, recognizing the existence of such incommunicable facts, admits the opinion of the only one in possession of these facts as evidence, admits them from the *necessity of the case.* So, again, a witness may have seen one man rush upon another and kill him; he may be able to give an opinion as to whether the latter had time to escape, because there are a variety of circumstances that could be pictured in his mind, but not detailed to the jury, which may constitute a large part of the aggregate upon which his opinion is based.

But again, in many cases, there are material facts upon which the triers of the cases, the jury, are not qualified, from their experience in the ordinary affairs of life to form an opinion, even when the facts have been admitted, or proved. Here again, from necessity, the opinion of some one competent to deal with them must be taken or the rule of best evidence be violated. Thus we have opinions admitted as evidence, based not upon facts within the knowledge of the witness, but upon facts testified to by others. As an example, in a suit against a railroad company for damages, in the destruction of fruit trees by fire, a nurseryman, who has never seen the trees, may give an opinion as to the damages, based upon the testimony of others. Here then, we see the entrance of the expert witness, the skilled witness—known as well to the Roman law as our own—admitted in accordance with the rule of the best evidence, and the necessity of the case, as the text-book says, "on questions of science, skill, trade and others of like kind," which witnesses "are permitted to give their opinions in evidence as persons of skill." A better definition of an expert, than this from from Greenleaf, might be asked for; but, whilst any one with a few illustrations will form a general definition of the term expert witness for himself, the word seems to elude definition in terms entirely applicable, or at least wholly satisfactory in all cases, as they arise in practice. Judges and law-writers, in consequence, furnish almost numberless phrases definitive and descriptive of the term "expert," sometimes restricted within narrow limits, sometimes expanded so as to include a portion of the hazy, doubtful zone that separates the expert from the ordinary witness. The difficulty of precise legal definition of the term scientific expert is still greater. Besides special and peculiar knowledge and skill, it seems to imply broader, more comprehensive knowledge, involving general laws and principles equally with specific facts, a result not of skill and observation alone, but of a wide range of reading and study as well, accompanied by that intellectual culture and discipline that permits the possessor to draw upon the whole range of human knowledge in settling questions that may arise. One of the simplest and most noted cases will furnish facts illustrative of the distinctive characteristics of the scientific expert, and also serve a further purpose. A man was accused of poisoning his wife by a draught of medicine containing arsenic. The chain of circumstances fixing his guilt seemed complete, yet there was wanting positive proof that the draught administered contained arsenic. The cup in which it had been was cracked by heating it on the stove, but the spilled liquid had been immediately carefully wiped off by the accused. All ordinary witnesses were at their limit. Ordinary human testimony could go no further. The question was put to the four scientific experts: Whether arsenic could still be detected upon the stove, after three months of constant use. Three of the experts said No; the fourth gave his opinion that it could. The accused, persuaded by his counsel, demanded an examination of the stove, trusting to the care with which he had removed the liquid. The experts and the judge went to the place. Half as much rust as would lie on the point of a knife was scraped from the designated spot, and in a short time evidence of the presence of arsenic, incontestable, satisfactory to all the experts, to the jury and to the judge was obtained. The single missing link in the chain of circumstances was thus supplied with inerrant certainty. Here, then, was evidence only obtainable through a scientific expert, and what was perhaps equally as important, only to be fully and satisfactorily confirmed by the opinions of others of the same character. Now this is certainly the very highest type of human testimony; at one time contributing facts of peculiar and unmistakable character, at others interpreting by infallible methods facts testified to by others. The scientific expert is in court then because of high peculiar value in his evidence. He has hardly forced himself in. He is scarcely in, in the first instance, by simple invitation but rather by the irresistible persuasiveness of a *subpœna*, which he is not at liberty to disregard any more than the ordinary witness. That he is in court to stay it is hardly necessary to assert, certainly not to argue. But with the rapid advance only of the past twenty-five years, in minute, detailed, exhaustive knowledge, in special knowledge, with the manifest tendency to precision in everything, even the sports of children, and at the same time with the broadening of the field of applications in all directions, all dumping in, as it were, new matter upon the courts for consideration, matter which they are in many respects unprepared, if not utterly incompetent, to deal with, it does not seem that the question of the future will be whether the scientific expert should be in court, but the grave question should be, as the pressing question is, whether his contribution may not be made more effective, less clouded and weakened than it now seems to be in the minds of many jurists, as the inevitable effect of a rigid system of jurisprudence, fashioned long before he was a recognized agent in forensic procedure.

In considering some of the sources of dissatisfaction with the scientific experts, perhaps one of the first to suggest itself, and one of the most prolific, is the vagueness of the legal definition of the term "scientific expert" before alluded to, but which on more careful consideration might rather be termed vagueness and variableness of the standard. Definitions of things are of ideals, and consequently definition is followed closely by the statement that the thing defined is non-existent. The ideal circle is defined, so the ideal solid, the ideal liquid; these definitions are only approached, never realized. Degrees of approach constitute the differences. A few minutes ago we broadly sketched a bundle of qualities that should be found in the scientific expert. But practically the courts are limited to the best experts extant in any field, though they may at times fall far short of the ideal. But it is to be feared that in many cases the experts fall below a reasonable and possible standard, and far below the standard that would be fixed by scientific men themselves, as well as below the exigencies of the case. This may easily be accounted for. A party presents a witness as an expert. The judge must pass upon his competency upon such examination as he can make. That decision, though not necessarily, nor even by unvarying practice, a matter of discretion, will not often be reviewed by a superior court. Often then the best solution, certainly the easiest, seems to be to admit, even where there may be grave doubt as to qualification, and to throw the burden upon the jury, already overburdened with questions, which the theory of trial by jury assigns them, questions which they are not qualified to deal with, although they may be fully up to the average in general intelligence. At a time when experts were not much beyond men in the ordinary avocations of life it may have been reasonable to require the jury to pass upon the " weight and credit to be given to evidence viewed in connection with all the circumstances," but under the changed circumstances of to-day, with experts of a character, and upon questions not dreamed of even a century ago, it seems to be straining a theory too far to put upon an average jury the decision of so grave a question, as to the character of the expert, which the court may not be able to settle satisfactorily. But for the theory it would not be thought of, if a system of jurisprudence were now being devised. Now among the results incidental to a liberal interpretation of the term by the courts are many that are regarded as the gravest evils of expert testimony. With doors wide open to incompetent persons, very slight pecuniary advantage, and still more frequently the incidental benefit attributed to notoriety and advertisement would cause them to seek entrance. As a result differences of opinion may be anticipated where knowledge is wanting as a basis. Then, too, the number of such experts in any case will be greater. The cross-examination, absolutely necessary to test such evidence, must be exhaustive and tedious. Trials are prolonged. The expense of the administration of justice is increased without furthering its ends, and withal often with incidental discredit not only of the testimony of experts, but in a measure of the whole judicial procedure which is responsible for them ; and the jury are often left in such a state of mental confusion that the evidence can only be weighed by counting the experts. Now the rule should tend toward a greater strictness in regard to the qualifications of experts, since the progress of science tends towards a greater degree of specialization in study, and consequently to more minute and extended evidence on the whole, with greater restrictions on the range of best evidence of any particular expert. If science stood still, or if forensic science was confined at all times to the same old ground, everything would be settled, but as it is, the new points at issue continually arising make new demands upon experts, which there may be few at first qualified to meet. We might fill in the evening with interesting cases illustrative of this point. The introduction of advanced scientific expert testimony is then hardly a matter of option. It is forced upon the courts by the fact that science is just as ready in the hands of the unscrupulous and dishonest to perpetrate the most flagrant wrongs as to aid in their detection, and that there is no advance in science that is not as accessible to the enemies of society as well as to society itself.

But another, even more prolific source of complaint than laxity of rule in the admission of experts, lies in the anomalous position of the expert in many respects, and under the best circumstances. He is legally a witness, an ordinary witness, but practically with extraordinary functions, and loaded with extraordinary responsibilities, and one might add, frequently loaded with extraordinary, and even absurd, expectations. As a witness he is subpœnaed by the same form, obliged to respond under the same penalties, to take the same oath; is subject to the same rules and restrictions, and the same treatment in court. He has no higher claim upon the State, or upon the parties for his time or his private professional knowledge, which constitutes his livelihood. He receives, in most cases, to be sure, from the party calling him, a fee agreed upon between them, and certainly out of proportion to those of other witnesses, even if it is not professional in magnitude. He assists the side on which he is called in working up its case. He suggests cross-examination of witnesses. He thus exhibits the character of a very willing witness, of a well-paid witness, combined with a great deal of the advocate. Now he cannot be held responsible for this position, but the system of jurisprudence, which not simply permits it, which has not simply taken him, but has forced him in, and which, apparently cognizant of all, seems only able to originate complaints, rather than to provide a different character for him; for there seems, indeed, in many of the adverse criticisms of experts, to be only a confession of weakness, rather than a disposition earnestly to consider the whole question with a view to the radical remedy of the evils. The human nature of the judge is recognized and provided against. Every safeguard is thrown around him to protect him from bias, or possible suspicion of bias, which would be almost as bad. The jury is selected so as to be free from bias, and is protected as well. Other witnesses are not expected to take the part the scientific expert is almost compelled to take. In fact, if deliberately planned, there could hardly be a net-work of conditions, devised, calculated to produce so many of the evils of scientific expert testimony, complained of, or to cloud this testimony of highest intrinsic value, having the highest degree of certainty, and in a field altogether its own. Thus, in the extract from *Taylor on Evidence*, stress is laid on "the facility and extent to which their views can be made to correspond with the wishes and interests of the parties who call them," "though conscientious they are biased," "they are embarked in a course," "they are selected on account of their ability to express a favorable opinion, the result alone of employment," "they are adroit advocates of the theory of the party calling them," "men of the highest character are apt to be prejudiced," and so forth. Now the worst views thus expressed may be admitted in many cases, and yet there is a pertinent question of fact suggests itself, viz: In how many cases does favorable opinion, or bias, if you please, precede the call of an expert, rather than depend upon the call? And the still more pertinent question: How many experts are not in the particular case because their opinions are not wanted by the party who consulted them. There seems to be in mind in the consideration of experts too much of a similitude to the attorney. An attorney is employed. As a rule, I suppose, he accepts employment without any very close examination of the case to see whether it is the right side that seeks his services. I do not know that legal ethics requires him look too closely into the matter. In any event, there is sure to be one attorney on the wrong side. This is incident to the profession. But I think it would be found that there are few cases in which a scientific expert is actively engaged on a side contrary to his convictions; and convictions resulting from a careful examination of the cases. He would feel that his character as a scientific man was too deeply involved, whilst the professional character of the lawyer would not be, but the worse the case sometimes the greater the professional credit. In many of the opinions quoted instead of "bias of experts," "convictions of experts" might be substituted, earnest convictions and convictions, or bias if you please, not produced by or dependent upon the call or employment, but upon expression of which the call or employment is based. The man of earnest conviction becomes the earnest, perhaps the adroit advocate of his theory, the enthusiastic aid of the attorney in preparing and even in conducting his case in court; and an attorney does well to secure his services, as well as his testimony, by a suitable pecuniary recognition of his worth to him, and there is no rule of ethics that I can find, that should cause the expert to refuse the reward of his labor, that would not apply equally to the attorney, so long as his testimony on the witness stand is without conscious untruth. On the other hand, neither is there anything in legal ethics to require a lawyer to select a lukewarm, half-convinced representative of his theory of the case, and we may assume that, with the whole range of scientific experts to select from, he never does. Illustrative cases of these statements are within the experience of many. That the expert should occupy this position of witness and quasi-advocate at the same time may very naturally be criticised. But it is permitted; more than that, it is expected, if he is well paid, that he shall assist in working up the case. Even more than this, he is a necessity in this *rôle*, as well as in that of witness, and the legal mind sees no impropriety in it whatever. A writer on this subject, who is keenly alive to the abuses of expert scientific testimony, in urging cross-examination as a means of exhibiting any inherent weakness of expert testimony, and recognizing that this requires an approximate degree of expert ability on the part of the cross-examiner, as cannot reasonably be presumed to belong to the legal profession, suggests, as one of the modes of informing himself, "the advice and explanations of his own skilled witnesses of the false or unwarranted positions and deductions which his adversary is likely to assume." If there were no one to do this work, and scientific expert testimony had to be accepted without cross-examination, or even feeble cross-examination, such as the ordinary attorney unaided might be able to give, the question of its exclusion in many cases might be a very proper one; and yet a seeming inconsistency, or rather incongruity, is imparted to the character of a witness who passes from the table of counsel to the witness stand to testify, not to facts, but to opinions; and as a consequence, we might expect his testimony to be misunderstood and harshly judged.

But in regard to the charge of bias, so freely made, it may be admitted that the scientific expert may at times be biased, but that is only admitting that he is made of the same clay as other men. The bias, if not produced by the call, would certainly not be more of a reflection on his character than upon the system of jurisprudence which renders a call based upon bias not only possible, but almost necessary, and which provides no other method for the introduction of scientific testimony. But bias may be in nowise incidental to the call. It may be a purely scientific bias, due to some peculiar view or theory. No kind of training will fortify a man against bias at all points. In his laboratory, in conducting his investigations, the scientific expert may keep himself free from bias. The judge upon the bench is free from bias by habit, rather than by conscious effort. But even the judge, placed in some novel position of great responsibility, which this judicial habit does not fit exactly, might lapse into a bias. It is but a few years since that the American people trusted the decision of a grave question to a tribunal made up of judges of the Supreme Court, of Senators and Representatives of high character, picked men; and yet the points before that tribunal were decided eight to seven, always the same eight, always the same seven, always along the same line of division. I think there is a feeling to-day, not of reproach for, or distrust of the tribunal, but that it was hardly fair to have imposed that work on that tribunal under all the circumstances, and that it will never be repeated.

Another source of misunderstanding between the legal fraternity and experts lies in the decided difference in mental attitude with which they come to the trial of cases, a difference that often tends to produce feelings other than those of mutual respect. This can be well emphasized by quoting again from the lecture on "Medical Expertism" by a learned judge. He admits, "that there is abroad in legal circles a tacit sentiment, that for the evils of the expert system their profession is nowise responsible, and that with the medical profession rests the primary liability for all the admitted ills of this department of jurisprudence," which he attributes to differences between the mind medical and the mind legal, regarding the professions as "types respectively of the inductive and deductive in science." But, even if such a difference be admitted, there is a wider difference in the motives. We may assume that the scientific man comes into court with the mental habits of the investigator and expositor of science. There is sincerity of purpose, a mental candor, a tendency to look for truth wherever it may be found, and to conceal nothing. The true scientific man would be very awkward in advocating a proposition he did not believe, even if he could be induced to do so. He would not prove at least an adroit advocate. He notes soon that the attorney is only intent on winning his case; that Strepsiades himself could not be less indifferent to the question of right in the case. And whilst he may regard the distrust of testimony on the part of the lawyer, as fully justified, and feel that his extreme scrupulousness in admitting as uniform truth any human testimony until it has been thoroughly sifted, may be the result of habit, or be due to his larger experience with it, he becomes slowly impressed with the other fact, that he has no desire for scientific truth which does not affect his side favorably, and that he has great aversion for, and desire to repress, what might affect it unfavorably. He may become impatient of cross-examination that does not seem to be altogether in the interest of truth, and irritated by rules that control him, and that, perhaps in his judgment, distort and mutilate his testimony, and his opinion of lawyers may be affected unfavorably. That I have not done injustice to the legal fraternity in attributing this difference of motive in dealing with scientific testimony, let me quote again from the lecture last noticed. It reads: "The lawyer discriminates between the practitioner and the expert, embodied though they be in one and the same person; at the bedside he reposes a practically unlimited confidence in the man as a physician and in his science; as an expert he regards him as a tool whose cutting edge he will employ, or dull, as exigency may require." The ground of dissatisfaction on the part of the expert seems to be displayed in that last sentence. In the trial of cases it is the art of law rather than the science of law which the scientific man comes in contact with. The practitioner and the court are concerned mainly with and solicitous about the distinctions and technicalities, the well-worn rules of practice, often *placita juris* rather than *regulæ juris*, the tools and machinery of the law, and the exercise of mental dexterity in their use and application. The rules themselves may have been formulated long before the scientific expert was known in the world of jurisprudence, and not in contemplation of him, and as far as he is concerned may not therefore be the perfection of human wisdom.

The criticism due to differences of opinion frequently exhibited by scientific experts can hardly be regarded as a serious matter by a profession characterized by differences of opinions on all conceivable points; the only settled opinions known to it being those of the court of last resort, which even claims the privilege occasionally of reversing itself. Differences of opinion among scientific experts are often doubtless due to differences in scientific character, resulting from the loose rule of admission. But there may still be honest differences between experts of highest character. I think such, however, it will be found, are rarely in regard to well-established facts, but oftener in regard to probable inferences from facts, whilst entire agreement would be marvellous in matters of theory and speculation. Courts and attorneys do not discriminate sufficiently between well-established scientific facts and scientific theories. Some of the most recent and far-reaching decisions of our highest tribunals have a basis of theory rather than of fact. In the cases cited in the beginning three experts gave an opinion that arsenic could not be found under the circumstances, a fourth thought that it could, further opportunity alone demonstrated the correctness of the latter, and brought all the experts into accord.

So, too, the tendency of the scientific expert to usurp the functions of the jury, or even of the court, magnified so greatly by legal minds, may possibly exist as a result of his ill-defined position, or perhaps from imitation of the good judge, who is credited with tending to enlarge his jurisdiction. This should easily be corrected, with the intelligent expert, by the rules and ample power of the court. There is no time, and it is not necessary to go further into the consideration of the evils and abuses of expert testimony. Sufficient has been given to indicate that there are two sides to the question; that the expert is not altogether to blame, but that the system of jurisprudence, with feebler powers of adaptation and assimilation has had changed conditions and new material thrust upon it more rapidly perhaps than at any other period of its development. The disposition is perhaps first to complain of innovation. But that must, and will soon, give way in the case of the scientific expert, to a disposition to consider more carefully how the highest utilization of this new source of evidence can best be secured, unclouded by unnecessary conditions. It will not be an easy task. It certainly should not be done hastily, or in a revolutionary spirit, nor be trusted to inexpert lawyers or legislators; but once seriously undertaken, in the proper spirit, it will be on the way to accomplishment. Practices of which courts have grown ashamed have been radically changed in not very remote years. Some of the directions of reforms have been indicated. Whether these should come by the slow process of judicial legislation, or by statutory enactment, is matter of indifference. As the under-workman of the legislature, as the judge has not been inaptly termed, is responsible for much, much might be left with him to reform, but the process may be too slow to be satisfactory. A more rigid enforcement of a higher standard for scientific experts is certainly largely in the hands of the judge, and as we have said would abate many of the most serious evils complained of. In this connection, the encouragement of regular professional experts might be of advantage. There is at times a disposition to disparage the scientific man who figures frequently, or professionally, as an expert, outside perhaps of medical cases. But there can be no question that such experts facilitate the trials of cases, remove many of the asperities, and economize much time. They acquire a familiarity with the rules of practice, and acquire a self-command, under cross-examination, of the most unreasonable and even exasperating character, which at times will allow it unopposed to expend its energy in useless directions in the shortest time. In a conversational discussion of this subject, the experience of a prominent attorney with a prominent scientific gentleman, who figures frequently in court as an expert, and of whose integrity, from personal acquaintance, I have no shadow of doubt, transpired. The attorney had encountered him frequently in trials. He had in cross-examination built a pen around him, as he expressed it, higher and higher, until he saw no possibility of his escape, when, in his words, he cleared the whole at a bound, and he came to regard him as impossible to trap. With a less experienced expert such examination might have been much more prolonged, than with one perfectly self-possessed, and perfectly sure of his position, and truth even might have suffered; but he could afford to allow the attorney to have his own way, seeing clearly the end from the beginning of the cross-examination. But besides the shortening of cross-examination, professional experts would greatly facilitate the procedure of the court by knowledge acquired of the character of the parties for and to whom evidence is to be given, as well as a power of presentation and exposition to suit the case. Such experts would not have to explain their meaning to a jury, and then, perhaps, have to explain the explanation.

We have seen that many of the most objectionable features of the expert witness originate in the mode of his entrance into court, and it is an allowable question, whether any modification could be made in the calling of the witness. Among the reports one judge expresses the opinion that, "expert witnesses ought to be selected by the court, and should be impartial as well as learned and skilful. A contrary practice, however is now probably too well established to allow the more salutary rule to be enforced." Another judge suggests, that the law should be so changed "that this class of witnesses should be selected by the court, and that this should be done wholly independent of any nomination, recommendation or interference of the parties, as much so to all intents as are the jurors." This would not make experts *amici curiæ* any more than before, for all witnesses should be regarded in that light, but it would be a provision, rather, to preserve that character to them, coupled as it is with a recommendation as to compensation, so intimately connected with it. It is not the fact of extra compensation, or that the compensation is paid by the party benefited by his testimony, that creates the unfavorable impression. The other witnesses are friends of the court, by whatever party they may be called, they stand upon the same footing as to pay; but here is a witness who is paid according to a private agreement, by one of the parties; the amount is their own private arrangement on which the court is not consulted, over which the court has no control, a circumstance that imparts to him, in high degree, the character of a friend of one of the parties; and these facts as to compensation are often elicited at a time, and in a way, calculated to impair otherwise valuable testimony, in the minds of the jury.

Again whilst a *subpœna* may be made to cover an expert, simply because "he is accomplished in a particular science, art, or profession," as well as a person who has from his own observation "knowledge of a fact pertinent to the issue to be tried;" and although it may command his presence, as in our State of Pennsylvania at least, without any claim for extra compensation, it cannot "compel him to examine the case, and to use his skill and knowledge to enable him to give an opinion." His testimony may accordingly only consist of impromptu answers, which may fall far short of the standard of best evidence the case is susceptible of. A lawyer, or a judge may be considered an expert on matters of law, and yet neither would give an off-hand opinion on all questions that might arise, nor might we desire it upon questions of great intricacy, or involving grave interests. But either could in a short time, from their professional familiarity with, and ability to consult, books, give an opinion that would be perfectly trustworthy. The same is true to almost an equal extent with the scientific expert. He can give impressions, not guesses, upon points which would rise to full grade of opinions and beliefs with proper time and facilities for investigation. His knowledge from books is as much a part of the knowledge from which he is permitted to testify, as that from his own experience. It has sometimes been suggested that under the Constitution the accused has the right to compulsory attendance of expert witnesses, and yet whilst with an ordinary expert witness it might be a right with some benefit, with a scientific expert indisposed to examine the case it might be an empty, fruitless right. Such a witness, though covered by the language, could hardly have been contemplated by the Bill of Rights. Now then as the State cannot command this evidence, and it is not obtainable, in most cases at least, without compensation, the recognition of the particular character of such evidence, and the regulation of the compensation might relieve it of some of its most objectionable features. The question is not so much whether the expert should be compelled to testify, as to whether he should in some degree at least be compensated for his professional time which is his own private property, and not be afflicted because of his professional knowledge. Private property is taken for public uses continually, but in all other cases upon just compensation. There cannot be the same plea of necessity for his evidence that would make it a public duty to testify as in case of other witnesses. The latter are in possession of specific facts which happened to fall within their own knowledge, and of which no others may be cognizant. At this point of compensation the law is variable and practice unsettled. In Pennsylvania, the scientific expert is an ordinary witness in all respects. He can be taken from one end of the State to the other on ordinary witness fees and mileage. In English practice extra compensation to a scientific expert may be taxed as part of the costs. The compensation is, however, based on the superior value of his time, rather than on the value of his services. It is not professional compensation. So in the Imperial Courts of Germany, the experts, whether of the class of permanent ones, appointed by the State, or those appointed in particular cases by the judge, can demand a certain payment, which, however, in this case also is regarded rather as a restitution in money for his loss of time, than as payment for his work. In the opinion previously quoted from Judge Redford, in regard to selection of jurors, he makes the additional suggestion to the end that experts may be appointed by the court, "that the compensation of scientific experts should be fixed by statutes or by the court, and paid out of the public treasury, and either charged to the expense of the trial, as part of the costs of the same, or not, as the Legislature should deem the wisest policy." In some of the United States, very few it is true, a move has been made in that direction. In Massachussets special compensation to experts for the defence is allowed to be paid out of the public treasury, thus insuring the effective attendance of a witness of this kind, resting not simply on compulsory process. With the regulation of the appointment, selection or employment of experts, whichever word may be used, and the question of compensation removed as far as possible from the decision of interested parties, many of the ugly features of scientific testimony will disappear, and, perhaps, much that is untrustworthy or dishonest.

In the discussion of the question more radical reforms are sometimes suggested, such as to have permanent experts appointed by the State, to be paid by the State as officers. So it has been suggested to give scientific experts determining functions independent of, or auxiliary to, the court and jury, to introduce a sort of fifth factor in judicial procedure. Any such innovations can only come with full consideration, and as time with its growing demands indicates, by process possibly of further differentiation, possibly by assimilation of reforms suggested by other systems of jurisprudence. But, whilst it might be a pertinent question in this connection, whether similar evils are complained of and to the same extent in continental practice in Europe, too much is not to be expected from this source. Excellencies of other systems might not bear grafting on the English stock. Systems of jurisprudence are growths, not aggregations, and Bacon rated as one of the excellencies of the Common Law that it was made for the English and not for another people. Still the scientific expert is equally recent in all systems, and treatment of him in one may have valuable suggestions for others.

As I have alluded to German practice on one point, a few others may be of interest. For certain matters and lines of business permanent experts are appointed by the State, but they are are not regarded as officers, but as employés for the time being. They have no official title, nor regular salary. The payment they receive is not enough to support them, but barely compensates them for their loss of time. For most cases the expert is appointed by the particular judge in the case, often on the demand of one or the other or both parties, but the choice of the expert lies within the discretion of the judge. He may appoint any man whom both parties suggested, or may also appoint a third man not suggested by either, but if both parties unite on one man he must listen to his testimony. If a question is involved for which regular legal experts are provided, these need only be, or can be appointed. The qualifications for such a regular expert are that he should follow that particular profession or line of business habitually, and for the purpose of earning his living. The number of experts in a case is not limited by law; it rests with the discretion of the judge. The status of the expert in court is almost analogous to other witnesses, but it is not a civic duty, as with witnesses, to give evidence in court except where a profession is followed publicly and for a livelihood. The text of his oath before giving testimony is different from that of an ordinary witness; and he need not be sworn at all if both parties unite in dispensing with such qualification. The systems of jurisprudence are so different comparisons are difficult. But there are some indications of a fuller recognition of an expert class of witnesses, but at the same time no suggestion of an expert class of Government officers.

I have thus endeavored, within the time limit of a very patient audience, to discuss the subject announced rather comprehensively and suggestively than minutely or even systematically, and I will have accomplished my purpose completely, if I have succeeded in presenting a few of its most salient features, in such a way, that the general public, outside of the professions involved, may have a juster view of the scientific expert and the position he occupies in forensic procedure, and that it may be impressed, to some degree with the fact, that the testimony of scientific experts is at present an important factor in the trial of cases, ready in the near future to add to this importance in directions we cannot even predict; that the courts are powerless to exclude or restrict it if they would; that its present status is unsatisfactory at many points, and demands the most serious consideration of all interested in the proceedings of our courts that its value be not impaired by unnecessary taint, and that the best evidence that the most advanced science has to offer is utilized in the trial of cases.

ROPE-POWER TRANSMISSION.

BY JAMES M. DODGE.

[*A lecture delivered before the Franklin Institute, December 2, 1892.*]

The lecturer was introduced by the Secretary and spoke as follows:

MEMBERS OF THE INSTITUTE, LADIES AND GENTLEMEN:

Rope-power transmission is comparatively a development of recent times. Although ropes were used in isolated cases for this purpose many years ago, it may be said, so far as this country is concerned, that the last ten years have seen the adoption of rope-power transmissions become more general and the system take a recognized place in the field of mechanical engineering.

There are two general systems in vogue, which may be designated as the "English" and the "American." The former employs one or more single ropes, whereas the latter uses one continuous rope and employs a tension carriage, operating on one of the turns of the rope, to insure a uniform amount of work being performed by each wrap around the wheels.

Wheels, or sheaves, used in connection with the rope for the purpose of transmitting power, are made with V-shaped grooves in the rims, the most commonly accepted angle being 45°. These grooves are made sufficiently deep to prevent the rope bottoming, or resting upon the bottom of the groove, the object of this being to increase the resistance to slipping and enable a moderate weight on the tension carriage to give sufficient driving force.

Sheaves used in conjunction with manila rope are made in two ways, the older method being to cast the sheaves with sufficient width of face for the number of grooves desired and to roughly core the grooves, so as to lessen the amount of iron to be removed by the turning tool in finishing them. It is necessary to cast the wheels sufficiently heavy to resist the pressure of the turning tool, in order to have the finished wheels as round as possible. It is almost impossible, however, to avoid a small amount of spring between the arms, so that upon careful measurement the wheel is found to be polygonal. This is notably the case when the cut is heavy, it being necessary, in order to obtain a good result, to take a roughing cut, which releases the skin tension of the casting and permits it to take a modified shape, due to the internal strains ever present in cast-iron wheels designed to have the outer surface removed from them by turning. Then a second cut is taken, and finally a finishing cut is made with a tool ground to the exact shape of one of the finished grooves, this last cut, which is made more to true up the inequalities of the previous work, removing but very little metal. In the foundry work connected with the manufacture of these wheels, it is seldom that a wheel having two or more grooves in it is so perfect that upon turning imperfections are not discovered. These, of course, if too numerous, render the condemnation of the casting necessary. If, however, the sand holes, or blow holes, in the turned surface of the sheave are not too large, they are filled with babbitt metal, and the sheaves are put in use. The amount of metal turned from castings for rope sheaves is astonishingly large; for instance, in the case of a five-groove sheave of forty-eight inches diameter, for one and one-eighth inch rope, the rough weight before turning was 698 pounds, and after finishing the weight was 567 pounds, showing that 131 pounds had been turned off the original casting. This proportion would, of course, vary somewhat, dependent upon the care taken in the foundry, but at the same time it is always greater than would be supposed.

The second and newer method of manufacturing sheaves is that practised by the "Link-belt" companies and differs from the already described method in two very important features. In the first place, the sheaves are not turned after being cast, great care being taken in the proportioning of the hubs, arms and rims, so that the castings can be made of extreme lightness, but being devoid of internal strain are very strong. The grooves are cast on green sand cores, a three-part flask being used. By this we mean the flask has a cope and a drag, as is common in all foundry work, but between them is placed what is known as the "third part" or "cheek piece," which holds the sand destined to form the grooves in the finished wheel. It has been found in practice that it is possible to cast sheaves in this manner that are fully as accurate as turned ones, and with an average saving in weight of 17·2 per cent. This saving in weight, of course, effecting a corresponding economy in the power required to operate a rope drive furnished with them.

The second radical difference between the "Link-belt" sheaves and the solid turned sheaves is, that the manufacture of multiple groove sheaves, or those having more than one groove, is effected by bolting together what are known as arm sections (which are really complete sheaves of one groove) and rim sections (which are simply grooved rims cast without arms or hubs). This plan makes it possible to vary the weight and strength of multiple groove sheaves by using a greater or less number of arm sections, dependent upon the size of the rope to be used and the varying conditions of their employment. After the sheaves are "built-up," as it is termed, they are bored out, and to show the trifling difference in weight between the rough and finished sheaves, I would state that a forty-eight inch five-groove sheave for one and one-eighth inch rope weighs in the rough 433 pounds, and when finished 423 pounds, or 144 pounds less than the finished solid-turned sheave referred to previously.

So great is the care taken in the casting of "built-up" sheaves, that the only finishing required in the grooves is that of smoothing the casting by holding a block of emery in the groove while revolving at a speed of about 120 revolutions per minute, the finishing of each groove in this way not occupying more than three or four minutes.

An incidental advantage of the multiple groove "built-up" sheave is, that after a rope drive is erected and the necessity arises for the transmission of more power than that for which it was originally designed, additional ring sections may be added to the sheaves, and by splicing in an additional piece of rope, the desired increased transmitting capacity may be secured.

It is obvious that in the use of a single rope making a number of wraps around two wheels, it is essential that the diameters of the grooves at the pitch line, which is the arc of contact of the ropes, must be uniform in all of the grooves in any one sheave; otherwise, there would be a tendency on the part of some of the wraps of the rope to travel faster than the others, which tendency must be counteracted by the slipping of the rope in some of the grooves, this, of course, resulting in a loss of power and also in the rapid wear of the rope. So important is this feature, that great care has to be taken in splicing the rope so that the diameter at the splice will be no larger than in the body of the rope. An increased diameter at the splice would, of course, make the splice travel around a larger circle on the sheave by its not being able to take as low a position in the V-shaped grooves.

It is impossible to splice a rope without impairing its strength at the splice, provided its diameter is not increased. What is ordinarily known as the "short splice," or the "long splice," as used by sailors, will not answer at all. It is essential that a splice (for instance, in a rope one inch in diameter) should be from ten to twelve feet long, and made with great care, so that after the splice is complete the tension to which the rope is subjected is evenly divided among the strands of the rope.

Durability of manila rope transmissions is dependent upon various conditions, the most important one probably being the quality of the rope. In order to make good rope it is necessary that the fibres employed in its manufacture should be long and of nearly uniform size. The fact that the fibres of manila have a rough interior and are of great strength in proportion to their weight, is an important factor in the strength of the rope when subjected to a tensile strain, but at the same time this very roughness becomes an element of destruction when the ropes are passing around sheaves which cause the fibres to slide upon each other so that the internal wear of a rope becomes a most serious agent in destroying it. A worn-out rope untwisted so as to expose the strands, will show a fine powder which has been chafed off the fibres. Of course, after this has been detached from the fibres, it leaves them weaker than in their original condition. It is also noticeable that the fibres of manila, being composed of elongated cells, are not perfectly adapted to continued bending.

In order to counteract the destructive tendencies enumerated, it is essential that the rope should be lubricated. This is accomplished in two ways, the first being by the introduction of a lubricant in the manufacture of rope; notably, as in the case of what is known as the "Stevedore," into which tallow and graphite are introduced at the time the rope is made, the effect being to increase the flexibility of the rope, increase its life and to render it to a degree water-proof, and also in the ropes of some other makes, which are laid with tallow. The second method is to coat the outside of the rope with a mixture of lampblack or graphite and grease, relying upon the working of the strands of the rope with relation to each other to work the compound through it. This latter method is practised on the Continent, and is also being made use of in this country to a considerable extent.

Some of the larger constructors of rope transmissions in England claim that manila rope should never be used under any circumstances; that cotton is the only fibre that will give satisfactory results. I have seen samples of a rope one and three-eighth inches in diameter, which had been in constant use ten hours a day for nearly sixteen years. This was a cotton rope, known as the "Lambeth," the peculiarity of its construction being that it was primarily made of cotton, but each of the four strands of the rope was covered with a number of tightly twisted yarns, forming a protecting envelope, which prevented cutting or wearing of any of the strands proper of the rope. Of course, cotton ropes are much more expensive than manila ones, and a rope such as the "Lambeth" must necessarily be the most expensive of those made of cotton.

It is unquestionably true, that in time cotton ropes will be more extensively used in this country, crowding out the use of manila; but it is a fact that the introduction of any radical departures in the field of mechanical engineering are only possible by offering not only a more satisfactory article than has formerly been used, but also a cheaper one. This fact has aided in the introduction of the manila rope drive, as in many cases it is not only the best means of transmitting power, but also the cheapest. Ultimately, and as users of rope drives become more familiar with their intrinsic advantages, they will be more ready to increase the original outlay and put in the best rope that can be made.

If manila rope transmissions are designed with good judgment and are properly erected, there is no possible doubt of their giving satisfactory results. The prevailing notion is, however, that as rope is flexible in all directions, rope drives can be constructed in a haphazard manner, without special care being exercised in getting the sheaves in exact alignment, and considerable criticism has been engendered by lack of attention to the important details. When borne in mind that a rope used for the transmission of power runs at a speed as high as 5,000 feet per minute in many cases, and as a rule the rope is run in close proximity to the ceiling, which is the hottest part of a room, it is not surprising that the rope rapidly becomes dry and correspondingly brittle; hence, the importance of lubricating it in some way, to counteract the drying tendency. It is not uncommon to find rope transmissions erected so that the sway of the rope will occasionally bring it in contact with a beam, which, of course, results in extremely rapid wear of the outside of the rope. The fact that conditions of this kind exist is sometimes hard to discover, as when the rope is at rest it may apparently have abundant clearance throughout the path of its travel. One case brought to my attention, in which the rope was being rapidly worn out, resulted in the discovery of the fact that in its passage through the wall of a building, the rope would sway and come in contact with the edge of a corrugated iron covering of the building. On calling this condition of affairs to the attention of the parties operating the drive they seemed quite surprised that such a trifling thing as an occasional touching of the rope on the corrugated iron should in any way impair the life and usefulness of the rope.

Manila rope is usually run under a working strain equal to three per cent. of its ultimate breaking strain and at velocities varying from 3,000 to 5,000 feet per minute.

To determine the power which any rope will transmit at a given speed, it is necessary to ascertain the nature and amount of the strains to which it is subjected while running, and then to find the exact part of the total working strain which is expended in performing useful work.

Generally speaking, ropes in the "American" system are subjected to three principal strains, viz: the strain due to the power transmitted; that due to centrifugal force; and that due to the tension carriage weight. Besides these three there are the minor strains, due to the weight of the rope, the internal resistance of the rope to bending and the strains required to make the rope enter and leave the wedge-shaped grooves. With good ropes, running in well-made grooves, the minor strains do not probably absorb more than five per cent. of the working strain of the rope.

As an illustration of the method of determining the horse-power of a rope in the American system, let us assume the case of a one-inch rope travelling at a speed of 4,500 feet per minute. The breaking strain of this rope, as given by the Plymouth Cordage Company, is 9,000 pounds, and according to the limitation imposed by good practice, the total working strain should not exceed three per cent. of this, or 270 pounds. Deducting five per cent. for the minor strains, we have 257 pounds, which represents the sum of the three principal forces.

In order to obtain the effective strain, or driving force, it is first necessary to find the strain due to centrifugal force. This force varies directly as the square of the speed, and may be found by multiplying the square of the speed in feet per second by the weight of one foot of rope, and dividing the product by thirty-two.

Now, the weight of one-inch manila rope per foot is ·33 pound, and the centrifugal force, therefore, equals

$$\frac{75^2 \times \cdot 33}{32} \text{ or about 56 pounds.}$$

Subtracting this from 257 pounds, we have 201 pounds as the sum of the strain due to the power transmitted and the strain due to the tension carriage weight.

Now a series of carefully conducted tests have established the fact that a weight of (say) fifty pounds on one end of a rope wrapped half way round a sheave having a 45° V-groove, will sustain, without slippage, about three and one-half times its weight at the other end of the rope. Assuming, for the sake of safety, that this ratio is as 1 : 3, it is evident, that to sustain a strain of 201 pounds on the tight side without slippage, it is necessary to maintain a tension of one-third this amount, or sixty-seven pounds, on the slack side. The effective strain, or driving force, will, therefore, be equal to the difference of these strains, or 134 pounds, which at 4,500 feet per minute will transmit

$$\frac{4{,}500 \times 134}{33{,}000} \text{ or 18·4 horse-power.}$$

In the same manner we find, that at a speed of 1,800 feet per minute, the centrifugal force is only nine pounds, and the effective strain is 166 pounds, transmitting nine horse-power; while at a speed of 6,600 feet per minute, the centrifugal force is 125 pounds and the driving force only eighty-eight pounds, transmitting 17·6 horse-power.

On reflection it is evident, that as the speeds are increased the centrifugal force increases, and the effective tension must be reduced to avoid overstraining the ropes. At a speed of about 4,800 feet per minute the ropes attain their greatest efficiency, *i. e.*, they will transmit more power with the assumed working strain than at any other speed, either higher or lower, although there is but little variation in the power transmitted at that speed and the power transmitted at either 4,200 feet per minute or 5,400 feet per minute, thus giving a wide range from which to choose. It is well to bear in mind, however, that the higher the speed the greater the wear of the rope, and that for this reason the slower speed is the more economical. All things considered, speeds of from 3,600 to 4,200 feet per minute are best.

It may be well to note, that for the working strain assumed, viz: Three per cent. of the ultimate breaking strain, forty diameters should be regarded as the minimum size of sheaves to be used. If it is necessary to use sheaves of smaller diameter, the working strain should be proportionately reduced; thus in the case previously considered, an inch rope at a speed of 4,500 feet per minute transmitted 18·4 horse-power; now if it is desired to use a 30-inch wheel as a driver, it is advisable to reduce the power transmitted to three-quarters of 18·4, or 13·8 horse-power. This rule does not only apply to the driving and driven wheels, but also to any intermediate idlers around which the rope may be called upon to bend.

The idlers of rope transmissions have usually been made with semi-circular grooves, permitting the ropes to rest upon the bottoms of them. It has been found better, however, in practice to use the V-shaped groove for all purposes, as it insures a revolution of the idlers at the same speed at which the rope is travelling, and thus prevents the wear due to the slipping of the rope in the grooves of the wheel. It has been shown, that idlers having semi-circular grooves in them become highly polished, while those having V-shaped grooves do not. Thus the demonstration that the ropes slip to a certain extent in passing over idlers with the semi-circular grooves, is complete.

The use of the tension carriage in the "American" system of rope transmissions is twofold. In the first place where a continuous rope is used passing over the grooves of two sheaves, it is obvious that the rope must be wound spirally around the two wheels, and that unless the rope in passing off the last groove of one of the wheels is not conducted back again to the first groove of the wheel, the drive would become inoperative, from the fact that all of the wraps of the rope would soon run off and leave the wheels without connection between them. In order to make this return, the wheel of the tension carriage is set at an angle so as to enable it to make the proper return of the rope. Secondly, the tension carriage is weighted so as to give the proper tension to the rope and serve as a corrective agent to the trifling inequalities that may exist in the sheaves or in the rope. It is by the weighting of the tension carriage that we are enabled to tell the exact amount of strain to which we are subjecting a rope. I might add, that the tension carriage being mounted on guides, it is capable of maintaining the proper tension of the rope even if the latter becomes considerably elongated by the strain put upon it or is variable in its length, due to atmospheric changes. This latter is especially noticeable in rope transmissions which are used wholly, or in part, out of doors, they being subjected to the action of rainy and dry weather.

The use of wire rope for the transmission of power I will only briefly touch upon, by stating that the economic use of it seems to be confined to transmissions of great length between centres. The sheaves employed have to be of very large diameter; otherwise the rope becomes crystallized and is of short life.

With reference to raw hide I might say, that its cost has prevented its general adoption, as it is cheaper to use an increased number of strands of manila rope to accomplish the desired result, though it has one marked advantage, inasmuch as it is possible to use it on sheaves of smaller relative diameter than in cases where manila rope is employed.

If possible, in running the rope care should be taken to have the bends all in one direction; as a rope bent in opposite directions will wear with much greater rapidity.

THE CHEMICAL SECTION

OF THE

FRANKLIN INSTITUTE.

[*Proceedings of the stated meeting held Tuesday, May 16, 1893.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, May 16, 1893.

Dr. WM. H. GREENE, President, in the chair.

A letter from Mr. F. A. Genth, Jr., acknowledging the receipt of the memoir of the late Dr. F. A. Genth, was read, and in response to a question contained therein relative to the embodiment of the Section's memoir in another to be prepared by the family, it was voted that the paper could be used in any way desired by the relatives of the deceased.

On motion of Dr. Hall it was voted that the *Zeitschrift für Anorganische Chemie* be added to the list of journals subscribed for by the Section.

Dr. Tuttle read a paper on "a process of treating mixtures containing sulphides of precious metals and copper." After the conclusion of the paper he called attention to the patented process of dissolving gold, etc., in a dilute solution of potassium cyanide. An animated and interesting discussion of the questions treated of by the author followed, and was participated in by Dr. Keller, Dr. Hall, Mr. Pemberton, Dr. Greene and Mr. Phillips. The paper was referred for publication.

Dr. Tuttle suggested as a good subject for investigation the action of sodium sulphide on silver in presence of water entirely freed from dissolved oxygen, with a view to detecting hydrogen, which, under the circumstances named, should be evolved if the usual action of a solution of sodium sulphide on silver takes place.

Professor Smith then read a paper by himself and Mr. Victor Lenher on "the action of ammonia gas upon molybdenylchloride." The paper was briefly discussed by the author and Dr. Tuttle and was referred for publication.

Dr. Wahl called attention to some samples of an abrasive material known as carborundum, made by subjecting a mixture of silica and coke to the heat of an electrical furnace. The material is a good substitute for emery and corundum, and even for diamond dust in polishing diamonds.

Dr. Keller followed with a conference on "Recent Contributions to our Knowledge of Metallic Reducing Agents." The subject was most admirably presented and called forth a vote of thanks. It was referred for publication in the *Journal.*

The Section then adjourned. WM. C. DAY, *Secretary.*

A MEMOIR OF FREDERICK AUGUSTUS GENTH.*

FREDERICK AUGUSTUS GENTH was born May 17, 1820, at Waechersbach, in Hesse-Cassel, where his father occupied the position of "Forstmeister" to Prince Isenburg. He received his early training in the gymnasium at Hanau. His university studies began at Heidelberg. While there, although he exhibited much interest in mineralogical and chemical studies, and made frequent botanical and geological excursions, he does not appear to have definitely decided upon his future career. His earliest papers, which he published in 1842, while still a student, in Leonhard-Bronn's *Jahrbuch*, were upon subjects having reference to conchology, geology and mineralogy.

From Heidelberg he proceeded to Giessen, where the fame of that greatest of all teachers of chemistry, Liebig, was attracting students from all parts of the civilized world. There were assembled around this master many men whose names have since become illustrious in chemistry.

When Genth entered the Giessen laboratory, he met among others the two assistants, Fresenius and Will, and as fellow-students with such men as Hofmann, Wurtz, Strecker and Varrentrapp.

The master mind of the head of the laboratory and the scientific atmosphere of the place, had doubtless a great influence upon the young student, and gave his studies a definite direction; but it was under the guidance of Fresenius that he began his chemical exercises. In later years, Genth was wont to express his indebtedness to this great analyst for having laid the foundation of what was later to become the field of his principal scientific work.

At the same time, however, he continued zealously to cultivate the mineralogical studies, and he seems to have given special attention also to crystallography. * * *

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* Report of a Special Committee of the Chemical Section. Read and accepted at the stated meeting held March 21, 1893.

Under Liebig's direction he made and published a chemical investigation of a new resinous body, which was given the name of masopin.

In 1843, he went to complete his university studies with Bunsen at Marburg. This eminent savant also had surrounded himself at this time with a circle of students, many of whom afterwards became famous. Among these appear the names of Kolbe, Frankland and Tyndall.

For three years he acted as Bunsen's assistant. His contributions to science during that time were numerous: a few of these related to geology, most of them, however, were on mineral-analytical subjects. The most important of the latter was an investigation of the metallurgical process of the Friedrichshütte near Riechelsdorf.

The results of this well-known research were embodied in the dissertation, which, in 1846, he submitted to the Philosophical Faculty of Marburg, which conferred upon him the degree of Doctor of Philosophy, after he had passed the required examination with high honors. * * *

In the following year, 1848, having meantime married, Genth came to this country. He took up his residence in Philadelphia, and here established an analytical laboratory. Most of his time was taken up with commercial work and with the instruction of young men. His leisure he devoted to original research. Thus he was occupied for more than twenty years.

In this time not less than fifty-six contributions from his pen have appeared, with notable regularity, in various scientific journals. His earlier papers appeared in Keller & Tiedemann's *Nordamerikanischer Monatsbericht* and the *Proceedings* of the Academy of Natural Sciences. His later work was published in the *American Journal of Science*, and several important communications appear in the *Journal of the Franklin Institute.*

He held, for many years, the post of chemist to the State Board of Agriculture of Pennsylvania, being the first to be elected to this office, and practically controlled the fertilizer trade of this State. One of the most prominent specialists in this branch of manufacture bears testimony that his official work was always regarded as being absolutely reliable. This position he held until the recent establishment of the Agricultural Experiment Station in connection with the State College, to which was transferred the conduct of all researches in the interests of agriculture.

He was also, for a number of years, mineralogist to the Second Geological Survey of Pennsylvania.

In 1872, he was elected to the chair of chemistry and mineralogy at the University of Pennsylvania. This position he held until 1888, when differences with the administration caused his withdrawal.

He was the recipient of many evidences of appreciation of his scientific work. He was a member of the National Academy, President of the American Chemical Society, and Honorary Fellow of the American Association for the Advancement of Science. For many years he was an active member of the Academy of Natural Sciences and of the Franklin Institute. He was an honorary member of our Section.

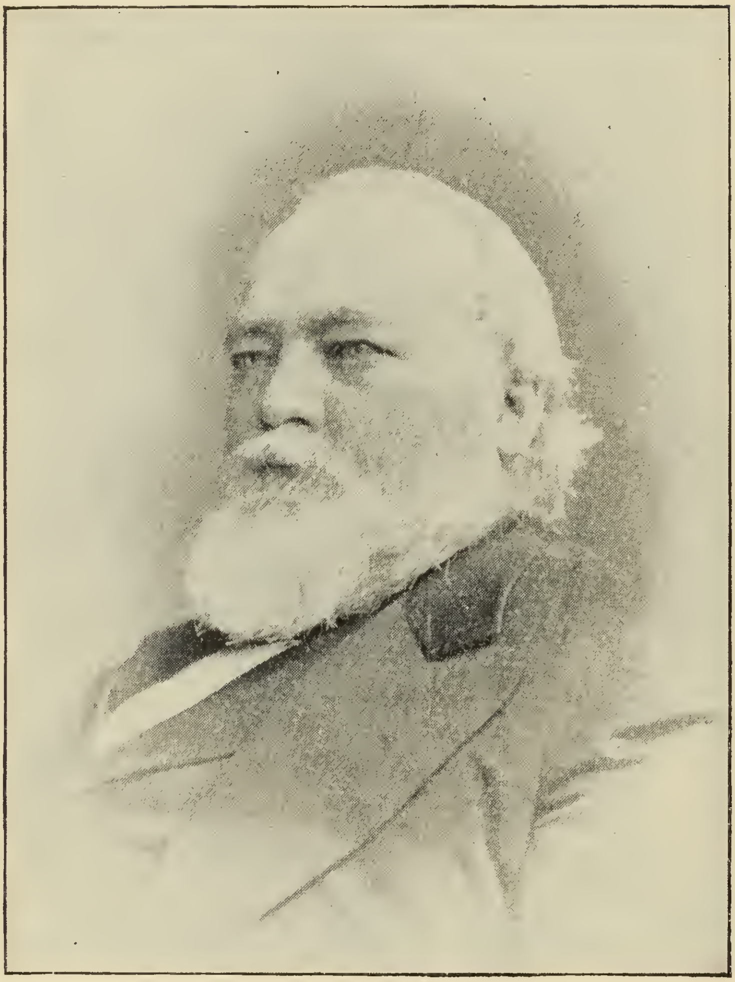
Notwithstanding the distractions of commercial work, to which he was compelled to devote much of his time, and, later on, those of a laborious professorship, he was able, thanks to his unflagging scientific enthusiasm and enormous capacity for work, to contribute more than one hundred papers embodying the results of his personal observations and researches during his professional career of about half a century.

In placing an estimate upon the scientific career of the subject of this memoir, it is not too much to say that he was one of the ablest mineralogists, and certainly the foremost mineral analyst this country has known.

His scientific labors embrace mineralogical, geological and chemical subjects, but valuable as are the results of his chemical researches, his fame will rest chiefly upon the contributions he has made to our knowledge of the minerals of this country. His name appears on almost every page of the records of mineralogy.

His innumerable observations and his careful analyses have helped to throw light upon every class of mineral

Jour. Frank. Inst., Vol. CXXXV. June, 1893.



FREDERICK AUGUSTUS GENTH.

(1820–1893.)

species. Of the more than one score of well-established species which he added to the list of our minerals, we need only mention a few, such as nickel gymnite (named genthite by Dana), whitneyite, cosalite, coloradoite, psittacinite, aguilarite, calaverite, lansfordite and nesquehonite; but he deserves no less credit for the elimination of doubtful species and the characterization of others that had been imperfectly described.

In connection with his work in this direction, we should not omit to notice the elimination of owenite, harrisite, coracite, cherokine, and Endlich's schirmirite, and his characterization of roscolite, hiddenite and herderite. His most important contribution to mineralogy is probably his monograph on *Corundum: Its Alterations and its Associated Minerals.* His ingenious interpretation of the metamorphoses exhibited by this mineral, upon which, as well as his numerous careful analyses, his conclusions as to the character of the alterative operations of nature were based, have now been generally accepted by mineralogists and geologists.

His preliminary report, on the mineralogy of Pennsylvania, is an invaluable guide to the mineral history of the State, and the same may be said of his report on the minerals of North Carolina.

His contributions to chemistry proper are less numerous, though some are of considerable importance. In this category undoubtedly must be placed his famous discovery of the "Ammonia-Cobalt Bases," the credit of which, certainly belongs to him, notwithstanding the almost simultaneous announcement of those compounds by Claudet and Frèmy. The joint investigation of these compounds by Gibbs and Genth is a classic research.

His much-quoted paper, on "The Metallurgical Process of the Friederichshütte," is replete with interesting results, notable among which is the discovery of an allotropic form of oxide of nickel contained in the metallic copper. Familiar to all the analytical fraternity is his method of analyzing chrome iron ore and his method of determining copper as oxide.

As a teacher Genth possessed, in a remarkable degree, the ability to impart knowledge. His method consisted substantially in inducing the student to cultivate the habit of close observation and reasoning rather than that of committing facts to memory. Many of his students have attained to positions of distinction, and will be able worthily to perpetuate his fame.

The personal character of the man could almost be predicted by those who never enjoyed the privilege of his acquaintance and friendship, from the sterling character of his scientific work.

He had in full measure the typical characteristic of the German nature, in his love for thoroughness and contempt for superficiality and sham. He was unaffected in manner, and though at times he may have exhibited a certain brusqueness even towards his friends and intimates, this eccentricity served only to attach them more closely to him. To them he was thoroughly devoted, and those who knew him best loved him most. His friendly interest in young men about beginning a scientific career exhibited one of the most charming traits of his nature, and the writers of these inadequate lines which they affectionately dedicate to his memory, gratefully recall from earlier days, the acts of considerate kindness and words of encouragement of the revered master whose life work is done.

His private life was blameless, and in his domestic relations, which were most happy, he was a devoted husband and father. He was twice married, and three sons and five daughters survive him.

WM. H. WAHL,
HARRY F. KELLER,
T. R. WOLF,
Committee.

A NEW METHOD OF REDUCING METALLIC OXIDES.

By Wm. H. Greene and Wm. H. Wahl.

[*Read at the stated meeting of the Chemical Section, held Tuesday, March 21, 1893.*]

In a previous paper by ourselves, presented at the January meeting of the Section, we gave an account of the various methods that have been proposed for the production of metallic manganese, and described a method which we had devised for the production of this metal, and which we believe to be adapted for commercial use, based on the reduction of one of the lower oxides of manganese by means of aluminum.

In the search for commercially available reducing agents applicable to the solution of the manganese problem we gave consideration to all the elements of which the known thermo-chemical data gave us reason to hope for an exothermic reaction with the oxides of manganese.

Among these silicon did not escape our observation, inasmuch as the heat of formation of its oxide SiO_2, according to the most reliable estimates, is sufficiently greater than that of $2MnO$ to permit us to expect that the desired reaction should take place.

The references in the literature of chemistry to the reducing action of silicon are not numerous. The only investigations that appear to have a direct bearing thereon are those of Gore,* who makes the observation that "crystals of silicon thrown upon melted argentic fluoride become red hot, undergo rapid combustion, forming fluoride of silicon and depositing silver." By adding crystals of silicon to melted black oxide of copper, the same author† observed a sudden incandescence which raised the temperature to full white heat; copper was also deposited and melted to a red metallic bead and could be hammered to a thin sheet. He noted also that crystals of silicon immersed in a solution of fluoride of copper, containing free hydrofluoric acid, instantly coat themselves with bright copper, and that when silicon is thrown into melted fluoride of sodium, bubbles of vapor are evolved which explode and burn with a yellow flame at the surface of the liquid. The silicon was found subsequently to have lost in weight.

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* *Chemical News*, **29**, 291.

† Gore, *The Art of Electro-metallurgy* (1877), p, 220.

More recently Warren* has published an account of a number of instructive experiments, which strikingly illustrate the energetic reducing properties of silicon. He notes the fact that metallic silicon, though a very stable and inert substance, yet when in admixture with a large number of metallic oxides, becomes at once oxidized, the oxide in admixture with the same becoming itself reduced. Litharge, for example, when mixed in excess with silicon and heated to dull redness, becomes reduced to metallic lead. With copper and all other readily reducible oxides, either a silicide, or, when the oxide is in excess, the pure metal is obtained. He observes that even the oxides of chromium, tungsten and molybdenum are reduced to the metallic state when heated with silicon.

The fact that silicon in the elementary form can only be obtained by indirect and costly methods, rendered any serious consideration of its availability for our purpose out of the question. The thought presented itself, however, that compounds of silicon might possibly be found to answer our purpose, and a very slight consideration of the subject encouraged us to believe that in the metallic silicides we had at hand a ready means of utilizing the chemical energy of one of the most powerful reducing agents.

It appeared reasonable to conclude also that the reducing power of such silicides might be found serviceable not only in the reduction of the oxides of manganese, but also in the reduction of many other metallic oxides.

Certain facts in connection with the metallurgy of steel and copper when given their proper interpretation appeared to strengthen this view. Thus, in one of the modifications of the open-hearth process of steel making, in which pig iron and scrap are melted on the hearth in contact with oxides of iron, not only the greater part of the carbon but also practically all of the silicon which is invariably present in small proportion is eliminated from the resulting steel, by the reaction with the oxides of iron, and finds its way into the slag as silicate.

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* Warren, *Chemical News*, **65**, 75.

Also, in the commercial operations of reduction, remelting and casting of certain metals and alloys, serious practical difficulties arise from the formation or retention therein of small quantities of oxide which have an unfavorable influence upon the strength, ductility and other desirable properties of the metals and alloys, and often render it troublesome to roll them or to obtain sound castings from them.

To counteract such difficulties, compounds in which silicon is present have come into use, either for the purpose of prevention or correction. We may refer as illustrations to the use of ferro-silicon in foundry practice and in the open-hearth process, and to the suggested use of copper, tin and zinc silicides to copper, tin and zinc and their alloys, all for the same general purpose of insuring the production of homogeneous metal and sound castings. In these cases the utility of the silicon appeared to us to be due manifestly to its energetic reducing action on the minute quantities of oxides retained in the molten metal, and to be strictly comparable to the action of phosphorus, magnesium, manganese, aluminum and other energetic reducing agents employed in the purification or refining of metals from small quantities of retained oxides.

Having satisfied ourselves from preliminary considerations of this nature that the use of silicon in the form of the metallic silicides might hopefully be applied as the basis of a commercial method for the reduction of oxidized ores of the metals, we proceeded at the first opportunity to make a number of experiments to test the correctness of our reasoning.

The requirements of iron founders and steel makers, we found, had caused a considerable demand for pig irons containing relatively high proportions of silicon. These are known to the trade as ferro-silicon, silico-spiegel and silico-ferro-manganese, the last two being so designated from their manganese content. These products may be described as silicides of iron, or of iron and manganese, containing from five to thirty per cent. of silicon, and a relatively low percentage of carbon. These silicides seemed adapted to our purpose.

We will confine ourselves here, for convenience, to the description of our method as applied to the production of ferro-alloys. It is obvious that in the production of such alloys, which, if useful at all, will find their principal application in the manufacture of special steels, the presence of carbon in notable proportion will be highly detrimental.

For this reason we require for our purpose a silicide containing as high a proportion of silicon and as low a proportion of carbon as possible. Silicon irons and spiegels containing as high as fifteen per cent. or twenty per cent. of silicon and with carbon not exceeding one per cent. can readily be obtained, and, as we are assured, by special selection of ores and fluxes, can be supplied on demand even higher in silicon than the figures just named. It is interesting also to note the fact that, as a rule, the quantity of carbon, in such silicides, varies with the silicon in an inverse ratio, the carbon decreasing as the silicon increases, and *vice versa.*

We may fully illustrate our method by describing its application to the production of a ferro-manganese; the object in view being substantially the manufacture directly from the oxide of a ferro-alloy sufficiently high in manganese and at the same time sufficiently low in carbon that it may be employed with economic advantage in the production of manganese steel, the deoxidation of the charge in the Bessemer converter, or on the open hearth.

The possible utility of the method may most strikingly be illustrated with reference to the ultimate production of manganese steel, an alloy that is known to possess certain unique and highly desirable qualities, but which presents certain practical difficulties in its manufacture in large quantities which thus far have proved to be troublesome.

By the way of explanation it should be stated that by the present method of manufacturing this alloy, which consists substantially in the addition of ordinary ferro-manganese to fluid iron, the proportion of manganese that can usefully be introduced into the steel is rigorously limited by the carbon, which to the amount of 5 to 6 per cent. is present in the ferro-manganese and which cannot be eliminated therefrom because of its affinity for manganese.

With this explanatory comment we proceed to describe the production of a ferro-manganese by the method which we propose. The chemistry of the operation is extremely simple. When a ferro-silicon (or other silicide) is heated in any suitable furnace chamber (which for our purpose is preferably lined with basic material, such as lime or magnesia) in contact with a metallic oxide (or a mixture of such oxides) and in the presence of a suitable base, such as lime, magnesia, or alumina, the oxygen of the oxides combines with the silicon forming silica, which at once unites with the base to form a more or less fusible silicate that separates as slag, while the metals set free combine to form an alloy.

The mode of our procedure is, precisely stated, as follows: We select a ferro-silicon or silico-spiegel adapted for our purpose and melt the same on the hearth of a furnace, or in a crucible. Then the manganese monoxide (or the proto-sesqui oxide) with which a fluxing material has been incorporated is added in proper quantity. The reaction takes place promptly, the silicon of the ferro-silicon seizes upon the oxygen of the manganese ore, and is thereby converted into silicic oxide which forms with the flux a liquid slag, while the manganese set free by the reduction of the ore combines with the molten iron set free from the silicide. The whole charge of manganese and flux may be added to the ferro-silicon at once, or the addition may be made by portions until a sufficient quantity of the oxide has been employed to utilize the reducing power of all of the silicon that was present in the ferro-silicon, thus reducing a chemically equivalent quantity of manganese oxide to the metallic state.

Assuming that we operate with a silicide containing iron

88 per cent., silicon 10 per cent., carbon 1 per cent. The reaction for simplicity's sake may be supposed to take place according to the equation

$$2\,MnO + Si = SiO_2 + 2\,Mn.$$

We would then employ silicide and manganese oxide in quantities that satisfy the above proportions, *i. e.*, for every 28 parts of silicon in the silicide 142 parts of manganese monoxide and a quantity of lime, manganese or alumina, or a mixture of these that will completely combine with the silicate to form a fusible silicate.

It is necessary, of course, to use a larger quantity of manganese ore than that required by theory, for the reason that a certain quantity of the manganous oxide is always seized upon by the silica and passes into the slag in the form of manganous silicate.

A charge of ferro-silicon (containing 10 per cent. silicon, 1 per cent. carbon) 100 pounds, manganese monoxide 70 pounds, lime 50 pounds, we have found to yield about 128 pounds of a metallic alloy having the composition: iron 70 per cent., manganese 29 per cent., carbon 0·7 per cent., silicon trace.

Assuming that the permissible percentage of carbon in a certain manangese steel is 0·5 per cent., then 100 pounds of a manganiferous alloy of the above composition will produce by mixture with 40 pounds of decarburized iron, 140 pounds of manganese steel of the composition iron 78·8, manganese 20·7, carbon 0·5, silicon trace.

In the preparation of a manganese steel containing the same percentage of carbon by melting decarburized iron with ordinary ferro-manganese containing 80 per cent. manganese and 5·5 per cent. carbon, the resulting metal would contain 92·23 per cent. iron and only 7·27 per cent. manganese. Or, making the comparison on the basis of equivalent quantities of manganese, the manganese steel made from the ordinary ferro-manganese would contain for 20·7 per cent. manganese, 1·4 per cent. carbon; that made by our process would contain for 7·27 per cent. manganese only 0·18 per cent. carbon.

In many cases it is obvious that a metal of the desired composition may be obtained directly by one operation on the furnace hearth. It is probable, for example, that for the production of a manganese steel of a given composition, the required proportions of scrap wrought iron and ferrosilicon of suitable composition could be melted on the hearth, in contact with the manganous oxide.

By procedures substantially like that described, but substituting for the manganous oxide, oxides of nickel, chromium and tungsten, we have succeeded in forming ferro-alloys of nickel (containing as high as 50 per cent. of this metal), chromium (with nearly 20 per cent. of chromium) and tungsten (with more than 50 per cent. of tungsten). With titanium, we have thus far obtained only doubtful results. In all these cases the resulting ferro-alloy is relatively low in carbon, and, as the method we propose does not involve the introduction of carbon either as the reducing agent, or from external sources, the carbon in the product being derived wholly from that which is contained in the ferrosilicon employed in the operation, we have reason to believe that we will be able to produce, on the commercial scale, ferro-alloys with any desired metals so low in carbon as to meet all the requirements of the metallurgical arts.

Thus far our experiments have been confined to the ferro-alloys and have been on the laboratory scale. It will be obvious, however, that the chemical reactions involved will hold good for other classes of alloys, and that alloys of copper, for example, with difficultly-reducible metals, may be obtained quite as readily by fusing the appropriate oxides with copper silicide.

In conclusion, the method which we propose, we believe, will enable the metallurgist advantageously to effect the reduction of numerous metallic oxides without the employment of carbon, and to produce numerous useful and important alloys.

ACTION OF THE HALOID ACIDS, IN GAS FORM UPON MOLYBDIC ACID.

BY EDGAR F. SMITH AND VICKERS OBERHOLTZER.

[*Read before the Chemical Section, April 18, 1893.*]

Debray (*Comp. rend.*, xlvi, 1098, and *Annalen der Chemie und Pharmacie*, **108**, 250), first called attention to the fact that a very volatile, crystalline compound of the formula $MoO_3 \cdot 2HCl$ resulted upon exposing molybdic acid, heated from 150–200° C., to the action of hydrochloric acid gas. It is true that the constitution of this volatile product may also be represented by the formula $MoO(OH)_2Cl_2$, which would make it a molybdenum hydroxychloride. Dismissing the question of constitution for the present, and considering the point of ready volatility, it seemed to us that this behavior might be utilized for the separation of molybdic acid from tungstic acid, as the latter apparently does not enter into volatile combination with hydrochloric acid gas. We, therefore, exposed weighed amounts of sublimed molybdic acid to the action of the acid gas and succeeded in expelling the molybdic acid completely from the porcelain boats containing it. Applying the same treatment to what we considered pure tungstic acid, we were greatly surprised to discover that very appreciable quantities of a sublimate, similar in every respect to that of molybdenum hydroxychloride were expelled from the boat. An examination of this product proved it to be the molybdic acid compound. In short, our tungstic acid was not pure. We, however, continued to heat portions of it in hydrochloric acid gas until a sublimate was no longer formed, when on mixing molybdic acid in known amount with the residual tungstic acid, we discovered that we could completely expel the former acid from the latter. Our next step was to observe the effect of heating anhydrous sodium molybdate in hydrochloric acid gas. The appended results show a quantitative conversion into sodium chloride, consequently a complete volatilization of the molybdic acid:

Na_2MoO_4 *in Grams.*	*NaCl.*	*NaCl Required.*
0·1302 gave at 150–200°, ...	0·0738	0·0739
0·1832, ...	0·1038	0·1040
0·2046, ...	0·1159	0·1162
0·3845, ...	0 2186	0·2183

As we were about to apply this method to the quantitative separation of molybdic and tungstic acids, both present as sodium salts, a closer scrutiny of the existing literature relating to this subject revealed that E. Péchard (*Compt. rend.*, **114**, 173, and *Zeit. f. anorg. Chemie*, **1**, 162) had already carried out the determination of molybdic acid and its separation from tungstic acid in this way with very evident success. Our own experiments confirm those of Péchard in every particular.

As previously observed, the tungstic acid that we thought pure contained molybdic acid. Traube (*Neues Jahrbuch für Mineralogie, Geologie und Paläontologie, Beilageband*, **7**, 232) has demonstrated that natural calcium tungstate, scheelite, and commercial tungstic acid obtained from the mineral wolframite, contain molybdic acid. E. Corleis (*Liebig's Annalen*, **232**, 265), has shown that the latter acid is even present in the "Wolframsaeure puriss" of trade, while Friedheim (*Zeit. f. anorg. Chemie*, **1**, p. 76) asserts that commercial sodium tungstate is strongly contaminated with sodium molybdate, and that even when exercising the greatest care in the process of purification the tungstate continued to show traces of molybdenum.

We found molybdic acid present in the purest sodium tungstate that we could get, and in the minerals scheelite and wolframite, when these were exposed to the action of hydrochloric acid gas at a temperature not exceeding 400° C. Hence, we are disposed to regard this method as excellently adapted for the detection of molybdic acid, as well as for the purification of tungstic acid and tungstates containing molybdenum.

Our original purpose having been the study of the behavior of molybdic acid in atmospheres of all the gaseous haloid acids, we may now briefly recount our experiences in those directions.

Action of Hydrobromic Acid, in Gas Form, upon Molybdic Acid.—The molybdic acid used by us was purified by converting the commercial acid into the ammonium salt, which was recrystallized a number of times and then ignited with air access. The product was sublimed very carefully from a platinum crucible. The hydrobromic acid was prepared by dropping bromine from a separatory funnel upon crude anthracene contained in a half-litre flask. It passed through a hard-glass tube, six inches in length, filled with anthracene, then through two U-tubes containing a paste of amorphous phosphorus, and two U-tubes provided with fused calcium chloride, while the sixth and last tube contained phosphoric anhydride. Having completed this circuit it was admitted to a perfectly dry combustion tube, into which had been introduced a porcelain boat filled with molybdic acid. The anterior portion of the combustion tube was closed with a calcium chloride tube to exclude all moisture. The heat used in the experiment was supplied from a combustion furnace. An ordinary thermometer was placed above the combustion tube; its bulb rested directly over the boat. In this manner we recorded the approximate temperature at which the reaction took place. As soon as the entire apparatus was filled with the gas, three burners of the furnace, directly under the boat, were lighted, and the heat gradually raised until it reached 200° C. A change took place almost instantly. Just beyond the boat appeared a heavy sublimate, with a color resembling that of potassium permanganate. Beyond this solid a brownish yellow colored liquid separated; on cooling it changed to long, beautiful yellow needles. These proved to be unstable, melting almost immediately when brought in contact with the air. At the expiration of an hour the passage of the hydrobromic acid gas was interrupted. The permanganate colored sublimate was removed from the sides of the tube as completely as possible, introduced into a porcelain boat and then carefully resublimed in a current of dry carbon dioxide. The compound sublimed in fern-like aggregates, consisting of dark red or purple red, shining, overlapping plates, extending from one side of the combustion tube to the other. They dissolved in water with liberation of heat. Their aqueous solution was colorless, but upon standing became blue in color. The crystals themselves changed in appearance on prolonged exposure to the air. By preserving them in an atmosphere of carbon dioxide they suffered no decomposition. Examined under a polarization microscope they showed their ability to polarize light, and that they consisted of aggregations of perfectly square plates. After the re-sublimation portions of the substance were weighed off in weighing tubes and analyzed. For the bromine determination the material was dissolved in as little cold water as possible, dilute nitric acid added, and this followed immediately with silver nitrate. The resulting silver bromide was treated in the usual manner. In estimating the molybdenum, the substance was brought into a weighed porcelain crucible and dilute nitric acid added. The solution was evaporated almost to dryness at a very gentle heat, when the crucible contents were treated with concentrated nitric acid, after which followed evaporation to perfect dryness. This operation was repeated and a gentle but direct heat applied to the crucible for periods varying from one-half to one hour. This was done to fully oxidize the molybdenum to trioxide. Portions of the new compound were mixed with freshly ignited litharge and heated in a current of dry air, using a perfectly dry combustion tube, provided with a weighed calcium chloride tube. The weight of the latter showed no increase, so that we were safe in considering our substance free from hydrogen.

ANALYSES.

Bromine Determination.

	Ag. Br.		*Bromine percentage.*
0·1334 grams substance gave	0·1793 gr.	=	57·19
0·3353	0·4499 "	=	57·09
0·0680	0·0908 "	=	56·82

The mean of these bromine percentages is 57·037 per cent.

Molybdenum Determination.

	MoO_3.		Molybdenum percentage.
0·2545 grams substance gave	0·12865 gr.	=	33·69
0·2916	0·1466 "	=	33·52
0·1115	0·0559 "	=	33·42

The mean of the molybdenum percentages is 33·54 per cent.

We experienced difficulty in wholly eliminating the traces of blue oxide in all of the molybdenum determinations, hence we look upon the results given above as low.

Regarding our compound as consisting of molybdenum, bromine and oxygen with the above percentages, and taking the oxygen by difference, we deduce as the most probable formula $MoO_2Br_2,MoOBr_2$ or $Mo_2O_3Br_4$—molybdenum sesquioxide tetrabromide. The theoretical requirements of this formula are: 34·28 per cent. Mo, 57·19 per cent. Br. and 8·57 per cent. O.

The only existing molybdenum oxybromide until the present has been MoO_2Br_2—molybdenyl bromide, discovered by Blomstrand on passing bromine vapor over the heated dioxide of molybdenum, or by heating a mixture of molybdic acid and boron trioxide with potassium bromide. It is mentioned as forming yellow, deliquescent tablets. For the sake of comparison, we made Blomstrand's compound by the second method. We found that when it was sublimed upon a previously heated portion of the tube it separated in "*mehr ausgebildeten Krystalltafeln auf; bei rascher Sublimirung in undeutlich krystallinischen Schuppen. Farbe schön gelbroth*" (Blomstrand, *Jour. prk. Chemie*, **82**, 439). Our compound, however, is formed simultaneously with that of Blomstrand when vapors of bromine are conducted over heated molybdic acid; the tube in which this reaction was made was freed from air by conducting bromine vapors through it and heat was not applied until we were satisfied that bromine alone was present.

The brownish-yellow liquid formed at the same time with the purple-red colored solid was crystallized in the tube in which it had been produced; the tube was then severed at a point between the yellow and red-colored compounds. The yellow immediately liquefied on exposure to the air. The liquid was collected in a small and previously weighed beaker; this was then placed in a sulphuric acid desiccator and the air exhausted. At the expiration of from two to three days the yellow needles had re-formed. The beaker and its contents were then rapidly weighed. Water was poured on the needles; their solution was colorless or slightly yellow tinged. On standing, the liquid slowly acquired a deeper yellow or reddish-yellow hue, and after twenty-four hours a blue oxide of molybdenum had separated.

The bromine and molybdenum of this product were determined in the same manner as in the purple-colored solid. We, however, had no difficulty in obtaining perfectly white molybdic acid in all the determinations that follow:

ANALYSES.

Bromine Determination.

	Silver Bromide.		*Bromine percentage.*
0·0950 grams substance gave	0·1403 gr.	=	62·83
0·2523	0·3700 "	=	62·50
0·2709	0·3967 "	=	62·37
0·0250	0·0365 "	=	62·12

The mean percentage equals 62·45 per cent.

Molybdenum Determination.

	MoO_3.		*Percentage of Mo.*
0·0946 grams substance gave	·0346 gr.	=	24·39
0·0946	·0337 "	=	23·75
0·1892	·0686 "	=	24·06

The mean of these percentages is 24·03 per cent. The formula we deduce from these results is $MoO_3 \cdot 3HBr$; it perhaps might be better represented as a trihydroxybromide $MoO(OH)_3Br_3$. The theoretical requirements are 62·02 per cent. Br and 24·80 per cent. Mo.

It is interesting to note that the long, yellow-colored needles of this compound were also obtained upon passing hydrobromic acid gas over the oxybromide of Blomstrand at a gentle heat. This change may easily be conceived as occurring if we grant the presence or production of water through the formation of secondary products.

$$MoO_2Br_2 + H_2O + HBr = MoO_3 \cdot 3HBr.$$

As we were not in a position to ascertain the true composition of the individual substance or substances from scarcity of material, we offer the above suggestion as a possible explanation for the appearance of the hydroxybromide in the manner just indicated.

Action of Hydriodic Acid, in Gas Form, upon Molybdic Acid.—A violent reaction occurred, in the cold upon passing the dry acid gas over molybdic acid; much heat was evolved, and iodine was liberated. The non-volatile product that remained in the boat possessed a bright violet color. It was exposed for a period of two hours to a temperature ranging from 45–50° C., during which time a continuous stream of dry and pure gas was conducted over it. Carbon dioxide was next introduced and passed for an equal period, while the temperature was maintained at 50° C. The results obtained from many analyses of this product pointed to the probable composition MoO_3HI, but as the quantity of iodine varied according to the length of time during which the hydriodic acid gas acted and with the temperature, we feel unable to assign any definite composition to the compound. It has seemed to us, from a careful study of the experimental results, that several derivatives were formed, but we were unable to separate them, and indeed by continuing the action of the gas for periods varying from six to eight hours, at the same time elevating the temperature from 105 to 120° C., iodine continued to separate. At last a violet-blue colored product remained; this appeared to be homogeneous. Prolonged action of the gas was without further reduction, therefore carbon dioxide was introduced to expel it. The blue colored product suffered no change on exposure to the air. We obtained what appeared to be the same substance by exposing the iodine-containing compound mentioned above to a temperature of 200° C., in an atmosphere of carbon dioxide. Indeed, mere exposure of the iodine compound to the air for some time gave the blue-colored derivative.

The same form of apparatus was used here that we have described with the oxybromides. The hydriodic acid gas was made from moist phosphorus and iodine. It was carefully dried.

Analyses.—An analysis of the blue-colored residue resulted as follows: The molybdenum was determined as under the bromine derivatives:

	Mo_3O.	*Mo Per Cent.*
0·1099 grams substance gave	0·1053 gr.	= 64·19
0·1017	0 0972 "	= 63·72
0·0807	0·0775 "	= 64·02
0·0959	0·0937 "	= 64·92
0·1386	0·1350 "	= 64·93

The mean molybdenum percentage is therefore 64·35 per cent.

Water Determination.

	H_2O	*Per Cent.*
0·1533 grams substance gave	·0138 gr.	= 9·00
0·1673	·0142 "	= 8·49

The mean of these percentages would therefore be 8·74 per cent. An intense red heat was required to fully expel this water content. The figures obtained would lead to an oxide of the formula $Mo_4O_{10},3H_2O$; this would require 64·21 per cent. Mo and 9·03 per cent. H_2O. Iodine was not found in the compound. The dehydrated residue was brown in color. Three determinations of its molybdenum content indicated it to be Mo_2O_5. As a result then of the action of hydriodic acid gas upon molybdic acid we can point to no definitely iodated product, but to a blue oxide, a product of reduction. In this connection we may direct attention to the observation of Schulze (*Journ. prk. Ch.* (N. F.), **29**, 440) that molybdic acid sustains reduction when heated with potassium iodide, air being excluded. The resulting products possess variable composition, but by the use of four parts of molybdic acid and one part of potassium iodide a definite product was prepared. It proved to be a new oxide of molybdenum, steel blue in color, crystalline and possessing metallic lustre. Its analysis gave results agreeing with the formula Mo_4O_{11}. Our reduction product is quite analogous to this, except that it is hydrous.

Action of Hydrofluoric Acid, in Gas Form, upon Molybdic Acid.—The hydrofluoric acid gas was evolved from fluorspar and sulphuric acid. It passed directly over the molybdic acid contained in a platinum boat and the latter in a platinum combustion tube from which a delivery tube led into a platinum flask, cooled by ice water. At a temperature ranging from 300–400° C., all the molybdic acid was converted into a volatile product that collected upon the anterior portions of the platinum combustion tube in crystals, having a peculiar red color. On holding the tube in which these crystals had been sublimed toward the light, it appeared to be filled with violet vapors of iodine; this was, however, due to reflection of light from the sides of the flat needle-like crystals. It is scarcely necessary to remark that before disconnecting the apparatus, carbon dioxide was conducted through it to expel the hydrofluoric acid. The platinum flask also contained the volatile molybdenum product. Much hydrofluoric acid was with it. This was expelled by the introduction of the carbon dioxide.

The new product when removed from the vessels containing it was found to be deliquescent, and it gradually decomposed into a blue oxide of molybdenum. It attacked glass, was insoluble or nearly insoluble in water, but dissolved to a colorless liquid in hydrofluoric acid. Portions of it were weighed off as rapidly as possible in platinum crucibles, and the molybdenum determined as trioxide by evaporation with nitric acid, followed by gentle ignition.

Molybdenum Determination.

	MoO_3.		*Mo. Per Cent.*
0·0526 grams substance gave, ...	0·0479 gr.	=	60·70
0·1066	0·0967 "	=	60·66
0·1166	0·1051 "	=	60·94
0·1265	0·1164 "	=	61·35

The mean of these determinations is 60·91 per cent. Mo. Formed in the same manner as molybdenum sesquioxide tetrabromide, we find that these results agree very closely with an oxyfluoride of analogous formula $Mo_2O_3Fl_4$, which would require 60·76 per cent. Mo. In experimenting with the above oxyfluoride we several times observed a slight quantity of a colorless liquid, which upon careful evaporation with nitric acid left a very appreciable quantity of molybdic acid. It may, perhaps, be an analogue of the very volatile $MoO_3 \cdot 2HCl$, and the unstable, liquid $MoO_3 \cdot 3HBr$. We endeavored to fix its composition, but experienced so great difficulty in getting material that we could safely consider sufficiently pure that we abandoned it entirely. The work attending its preparation is anything but pleasant and the yield exceedingly uncertain.

But one other oxyfluoride of molybdenum is known; namely, that prepared by Schulze (*Jour. prk. Chemie* (N. F.), **21**, 442), by fusing metallic fluorides together with molybdic acid with the exclusion of air. It has the constitution represented by the formula MoO_2Fl_2.

Reviewing the action of the gaseous haloid acids upon molybdic acid we observe:

(1) That hydrochloric acid gas converts the acid into a solid, very volatile product $MoO_3 \cdot 2HCl$.

(2) That hydrobromic acid changes molybdic acid to a volatile brownish-yellow liquid, $MoO_3 \cdot 3HBr$, forming long yellow needles at low temperatures and under diminished pressure, as well as a beautifully crystallized solid of the formula $Mo_2O_3Br_4$.

(3) That hydriodic acid reduces molybdic acid to a new oxide $Mo_4O_{10} \cdot 3H_2O$.

(4) That hydrofluoric acid converts the molybdic acid into at least one well-formed but volatile product, having the constitution represented by the formula $Mo_2O_3Fl_4$.

Püttbach (*Annalen*, **201**, 137) divides the known molybdenum oxychlorides into two classes:

Saturated.	*Unsaturated.*
$MoOCl_4$	$Mo_3O_3Cl_7$
$Mo_2O_3Cl_6$	
$Mo_3O_5Cl_8$	$Mo_2O_3Cl_4$
MoO_2Cl_2	

But one oxybromide is known. Its formula is MoO_2Br_2. Our experiments add to this, the compound $Mo_2O_3Br_4$, which would correspond to $Mo_2O_3Cl_4$. The latter is light brown in color, while the former possesses a deep purple color. Schulze's oxyfluoride would correspond to MoO_2Cl_2 and MoO_2Br_2, while that obtained by us corresponds to $Mo_2O_3Cl_4$ and $Mo_2O_3Br_4$. Püttbach's division presupposes the presence of a sexivalent molybdenum atom in the saturated members, while the unsaturated are regarded as derived from two molecules of $MoCl_5$ by the substitution of oxygen for equivalent amounts of chlorine. Our oxybromide, $Mo_2O_3Br_4$, and oxyfluoride, $Mo_2O_3Fl_4$, may be looked upon as possessing similar origin, although their corresponding pentabromide and pentafluoride are unknown. The compound $MoO_3{\cdot}3HBr$, like $MoO_3 2HCl$, presupposes the presence of a sexivalent molybdenum atom and may be properly considered a hydroxybromide, represented by the formula $Mo(OH)_3Br_3$, a derivative of the unknown hexabromide $MoBr_6$.

Chemical Laboratory of the
University of Pennsylvania, April 15, 1893.

THE ELECTRICAL SECTION

OF THE

FRANKLIN INSTITUTE.

[*Proceedings of the stated meeting, held Tuesday, April 25, 1892.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, April 25, 1893.

Mr. E. G. WILLYOUNG, President in the chair.

The stated meeting of the Section was called to order by the President at 8.10 P.M. There were present fifty-seven members and visitors. The minutes of the previous meeting were read and approved. The treasurer reported a balance of $36.91 in the treasury, and presented bills amounting to $10.32, which were ordered paid.

The meeting was then informally adjourned to allow the members to see the working of the telautograph, the recently perfected invention of Prof. Elisha Gray. The meeting was called to order again at 9.15. A committee, composed of Prof. E. J. Houston and the President, was appointed to endeavor to secure Prof. Elihu Thomson to show before the Electrical Section some results of his most recent work.

The President and Mr. Carl Hering were appointed a committee to provide for lunches at the next two meetings.

Mr. C. Billberg presented two curves taken from one of his sixty-five horse-power motors, illustrating the influence of the iron wire wound over the whole surface of the armature. The one was platted from a test before the iron wire was put on, and the other after, the latter showing a gain of about ten to eleven per cent. in E. M. F., with the armature making in both cases 665 revolutions per second, and having the same field excitation.

Mr. Willyoung showed some interesting experiments with Crookes tubes.

The paper, by Messrs. Willyoung and Northrup, on "Some Methods of Varying the Sensibility of Galvanometers," was referred for publication.

The meeting then adjourned. R. H. LAIRD, *Secretary.*

BOOKS RECEIVED.

[In sending books for notice in the *Journal*, publishers are requested, for the information of the reader, as well as for their own advantage, to give the price. This announcement by title will be followed, in most cases, by a review, which will appear at the earliest opportunity.]

Adriance, J. S. Laboratory Calculations. New York: John Wiley & Sons. 1893. 12mo.

Alheilig. Corderie. Cordages en Chanvre et en Fils Métalliques. Paris: Gauthier-Villars et fils and G. Masson. 12mo. Price, 3 francs.

Army and Navy Journal Manual of Guard Duty. New York: Army and Navy Journal. 1893. 32mo.

Bedell F. and A. B. Crehore. Alternating Currents. New York: W. J. Johnston Co. 1893. 8vo.

Benjamin, P. The Voltaic Cell: its Construction and its Capacity. New York: John Wiley & Sons. 1893. 8vo. Price, $5.

Bertin, L. E. État Actuel de la Marine de Guerre. Paris: Gauthier-Villars, n. d. 12mo. Price, 3 francs.

Bovey, H. T. Theory of Structures, and Strength of Materials. New York: John Wiley & Sons. 1893. 8vo. Price, $7.50

Brainard, F. R. Knots, Splices, Hitches Bends and Lashings. New York: Practical Publishing Company. 1893. 24mo. Price, $1.

Buberl, J. Bericht des vom Oesterreichen Ingenieur und Architekten-Vereine eingesetzten Comites zur Aufstellung von Typen für Walzen. Vienna: Society. 1892. Price, 5 marks.

Bureau des Longitudes. Annuaire, pour l'an 1893. Paris: Gauthier-Villars et fils. 12mo. Price, 1 franc 50 c.

DeLaunay, L. Formation des Gîtes Métallifères. Paris: Gauthier-Villars et fils and G. Masson. 12mo. Price, 3 francs.

Dixon's American Graphite Pencils. Catalogue and Price-list. Jersey City. 8vo.

Enterprise Mining Company. First annual report. September 30, 1892, with a description of the property. By Leo Von Rosenberg. New York. 1892. 4to.

Foster Engineering Company. Newark N. J. Illustrated Catalogue.

Gilbert, Wm. On the Loadstone and Magnetic Bodies. Translated by P. F. Mottelay. New York: J. Wiley & Sons. 1893. 8vo. Price, $4.

Goodhue, W. F. Municipal Improvements. A Manual of the Methods, Utility and Cost of Public Improvements, for the Municipal Officer. New York: John Wiley & Sons. 1893. 12mo.

Grant, G. B. Treatise on Gear Wheels. Lexington, Mass.: Author. 1893. 8vo. Price, 60 cents.

Grimshaw, R. Engine-room Chat. New York: Practical Publishing Company. 1893. 12mo. Price, $1.

Handy Sketching Book for Engineers and Draftsmen. New York: Spon & Chamberlain. 1893. Price, 25 cents.

Holman. S. W. Discussion of the Precision of Measurements. New York: J. Wiley & Sons. 1892. 12mo. Price, $2.

Houston. E. J. Electrical Measurements. New York: W. J. Johnston & Co. 1893. 12mo.

Infantry Drill Regulations. New York: Army and Navy Journal. 1893. 32mo. Price, 50 cents.

Jean, F. Industrie des cuirs et des peaux. Paris: Gauthier-Villars, n. d. 12mo. Price, 3 francs.

Kapp, G. Alternating Currents of Electricity: their generation, measurements, distribution and application. New York: W. J. Johnston & Co. 1893. 16mo.

Koll, O. Die Theorie der Beobachtungsfehler und die Methode der Kleinsten Quadrate mit ihrer Anwendung auf die Geodäsie und die Wassermessungen. Berlin: Jul. Springer. 1893. 8 + 323 + 31 p. O. Price, 10 marks.

Knudson, A. Triangular Surveys from Single Stations. San Francisco. 1892. 24mo.

Langlois, P. Le Lait. Paris: Gauthier-Villars, n. d. 12mo. Price, 3 francs.

Madamet, A. Distribution de la Vapeur. Paris: Gauthier-Villars, n. d. 12mo. Price, 3 francs.

Massachusetts Institute of Technology. Department of Civil Engineering. Boston. 1892. 8vo.

Michie, P. S. and F. S. Harlow. Practical Astronomy. New York: John Wiley & Sons. 1893. 8vo.

The Mineral Industry: its Statistics, Technology and Trade, in the United States and other countries, from the earliest times to the end of 1892. Vol. I. Edited by Richard P. Rothwell. New York: Scientific Publishing Company. 1893. 8vo.

Parker, E. W. Coal. Extract from the "Mineral Resources of the United States." Calendar year. 1891. Washington: Government. 1892. 8vo.

Public Ledger Almanac for 1893. Philadelphia: Geo. W. Childs.

Religious Liberty Library. No. 7. March, 1893. Appeal and Remonstrance. Resolutions adopted by the General Conference of Seventh-Day Adventists. New York: International Religious Liberty Association. 1893. 24 pp. O. Price, 3 cents.

Sanford, F. Some Observations upon the Conductivity of a Copper Wire in Various Dielectrics. Palo Alto: Leland Stanford Junior University. 1892. 8vo. Price, 50 cents.

Standard Thermometer Company. General Catalogue. No. 25. Peabody, Mass. 4to.

Swinburne, J., and C. H. Wordingham. Measurement of Electric Currents. New York: D. Van Nostrand Company. 1893. 24mo. Price, 50 cents.

United States Coast and Geodetic Survey. Determinations of Gravity with Half-second Pendulums on the Pacific Coast, in Alaska and at Washington, D. C., and Hoboken, N. J. By T. C. Mendenhall. Appendix No. 15. Report for 1891. Washington: Government. 1892.

U. S. Navy Department. Annual Report of the Chief of the Bureau of Steam Engineering for the year 1892. Washington: Government. 1892. 8vo.

Viaris, Marquis de. L'Art de Chiffrer et Déchiffrer les Dépêches Secrètes. Paris: Gauthier-Villars, n. d. 12mo. Price, 3 francs.

Wilson, H. M. Manual of Irrigation Engineering. New York: John Wiley & Sons. 1893. 8vo. Price, $4.

BOOK NOTICES.

A Manual of Irrigation Engineering. By Herbert M. Wilson, C.E. 8vo. 352 pp. New York: John Wiley & Sons.

The rapid settlement of the territory west of the 100th meridian, and the great demand for water for irrigation, mining and manufacturing which has been so ably advocated by the Director of the U. S. Geological Survey, has created a demand for more literature bearing on this important subject. Hence, there have appeared recently a number of important publications on this topic, amongst which we note the above work by Mr. Wilson, Member Am. Soc. of Civil Engineers. His aims have been to produce a book of practical use to students and irrigation companies by eliminating ambiguous or complicated hydraulic formulæ and giving descriptions of works actually built and doing good service. In this he has been successful, while in India irrigation works have been very expensive and have not been a financial success, there are sections of the United States where the conditions are favorable to such enterprises, but they should be carefully considered from the standpoint of the engineer and it is here that the book will be found to be of value, as it gives a table of cost of irrigation in the arid regions of the United States. It treats of rainfall, evaporation, alkali, drainage, sedimentation, measurement quality, dams, wells, storage reservoirs, sluices, flumes and kindred subjects, and is abundantly illustrated with well-selected works in existence.

The "make up" of the press work might, we think, be improved in some instances. (pp. 184–294–320–327.) H.

The Yale and Towne Manufacturing Company Catalogue. No. 14. Locks and Hardware. Stamford, Conn., U. S. A. 1893. With price book.

This catalogue marks a decided innovation in the make-up of such works, in that the practice of using full-sized illustrations is plumply abandoned and the volume thus reduced to reasonable size.

In it is presented for the first time the company's new "paracentric" lock, the peculiarity of which lies in the construction of the keyway "with continuous longitudinal barrier, in planes normal to the plane of motion of the pin tumblers, these barriers projecting from opposite sides of the keyway past its centre line and interlocking so deeply as to practically preclude the use of any picking instrument to vertically operate the tumblers."

The catalogue is a model of thoroughness, excellence of arrangement and typographical beauty, and reflects the highest credit upon the intelligent industry of Mr. H. H. Suplee, the company's editing manager. T.

Photographic Mosaics. An annual record of photographic progress. Edited by Edward L. Wilson. Twenty-ninth year. New York: Edward L. Wilson. 1893 12mo. Price, $1.

Much need not be said of this useful little hand-book. A publication which has been known and used by photographers for twenty-eight years will need no special praise. In the opening article the work in photography during the year 1892 is reviewed by the editor. He also contributes six other papers, on various subjects, which will be of great value in the studio. Dr. E. Liesegang and Dr. J. M. Eder furnish each an article on "Metol."

Leon Vidal, in a short essay, gives us some of his views on the "Direct Reproduction of Colors."

Among other important subjects discussed we select, at random: "A National College of Photography," by C. T. Stuart; "Bromide Paper," by A. R. Dresser; "Thickly Coated Plates," by Chapman Jones; "Reception-room Duties," by M. Phillis Bell.

Another valuable feature is the full-page plates, of which there are more than eighty, reproduced from photographs taken by artists in every part of the world. They illustrate, better than pages of letter-press, what can be accomplished with a camera reinforced by artistic taste.

The book should be read by every photographer, amateur as well as professional. A. R.

Alternating Currents of Electricity. Their generation, measurement, distribution and application. By Gisbert Kapp, C. E. With an introduction by Wm. Stanley, Jr. 1893. New York: The W. J. Johnston Company, Limited, 41 Park Row. Price, $1.

The rapid development of alternating currents, and the great part they are destined to play in the transmissions of power, have caused an increased interest in the subject, but unfortunately it has heretofore been presented in such a manner as to be beyond the reach of the great body of readers.

In the present work the principles are developed in a simple manner that can be followed by any reader, and the various applications are sketched in a broad and instructive way, that clears away the many mysteries with which they are supposed to be surrounded. The few mathematical formulæ in the book are confined to appendices.

The first four chapters are devoted to explaining alternating currents and their measurements, and the succeeding three chapters are on the principles and design of alternating current machines and transformers. Chapter VIII is on alternating central stations, and Chapter IX on the parallel coupling of alternators.

The remaining chapters, which are particularly valuable, treat of various forms of alternating motors, especial attention being paid to the explanation and discussion of multiphase motors. This difficult subject is treated so clearly that the attentive reader should be enabled to form as clear an idea of these new forms as of the simpler continuous current machines.

The treatment throughout is thoroughly practical, and the data and discussion on the design and construction of apparatus will be found useful and helpful to the electrician and designer. To the student and the general public interested in the subject this work should have a warm welcome, as it brings within their comprehension one of the most important and interesting subjects in applied electricity. W.

Original Papers on Dynamo Machinery and Allied Subjects. By John Hopkinson, M.A., D.Sc., F.R.S. New York: The W. J. Johnston Company, Limited. 1892. 249 pages, 98 illustrations. Price, $1.

This collection includes all the papers on electro-technical subjects published by the distinguished author, several of which have had an important bearing on the advance of electrical science. Perhaps no other contributions to electrical literature since the days of Faraday have been of more importance as those contained in the present volume.

In the first paper that invaluable aid to the study and design of dynamos, the characteristic curve, was first announced, and the following three papers are devoted to developing its applications.

The fourth and fifth papers, on the theory and design of continuous current dynamos, furnished the fundamental principles upon which the design of such dynamos is now based.

The sixth paper established the important principles in regard to coupling alternating current machines; the next three papers are on the transformer, and the remaining two are on the "Theory of the Alternate Current Dynamo and Electric Light Houses," respectively.

These papers, with the authorization of Dr. Hopkinson, are for the first time published in a collected form and rendered accessible to the general public, and they should furnish a fruitful source of inspiration to those in search of knowledge at first hand. W.

How to Become an Engineer. By George W. Plympton. Van Nostrand Science Series. No. 100. New York: D. Van Nostrand Company. 218 pp. Price, 50 cents.

The work defines the various classes of engineers, military, civil, mining, electrical, hydraulic, sanitary and mechanical. It gives extracts from distinguished authors relative to the profession and the curriculum of the Rensselaer Polytechnic School, closing the second chapter on the thirty-second page, with the remark that "other institutions in this country, affording similar courses of study, are Cornell University, Princeton College, Rutgers College, Lehigh University, Stevens Institute, Polytechnic Institute of Brooklyn and Michigan University."

In this limited test of American institutions it is to be observed that with the exception of the University of Michigan and Cornell, they are all within fifty miles of New York City; their curricula are very dissimilar and some of the most prominent technical schools of the United States are not even referred to, notably Columbia School of Mines and the Massachusetts Institute of Technology.

If the object of the book was to guide a young man in the preparation for or selection of an engineering profession, the data furnished are certainly very meagre and unsatisfactory so far as they apply to the American youth.

It is safe to say that the majority of the applicants for such information is to be found amongst those who have not had special advantages in the way of general preparatory or culture studies, but who are artisans, and who can only pursue their studies at night and to them an outline of a simple course, giving the names of books to be consulted and occasional hints as to applications would be of value.

The remainder of the work is a description of foreign methods, not specially applicable here, but even in this part of the book we regret to find statements which hardly represent the present methods, *e. g.*, the apprentice systems of a few decades ago are giving place in England to the regular technical school, some of which the author mentions in his syllabus. The work closes with extracts from addresses and reports, compiled from various sources, and although it contains much material which is of interest to instructors and teachers, it does not seem to answer the query propounded in its title so far as it applies to the American youth in a very satisfactory manner. It has, however, the merit of showing that to attain eminence in the profession requires many years of general and special training for which comparatively few have either the time or the means to spare, and it would be a valuable addendum if the writer would give a symposium of the results attained by those who started in the race. H.

Engineers' Surveying Instruments: Their Construction, Adjustment and Use, By Prof. Isa O. Baker, University of Illinois. New York: John Wiley & Sons. 8vo. 386 pp.

The title of this work sufficiently explains its scope, which includes all of the ordinary instruments used in the various kinds of surveys, with the notable exception of the sextant. This omission is important when it is considered that a good pocket sextant is a substitute for many other less portable instruments. The recent use of the camera also as a valuable aid in topographical work should not be ignored. The subject is treated with Professor Baker's usual perspicuity; is clear and full; with illustrations, tables, forms for notes and examples. There is one point upon which more stress might have been laid, viz: the practical value of the limits of errors; or, in other words, the relation of the scale and the instruments in determining how much care and time should be expended in collecting data for different kinds of work, and the consequent organization of the corps. A few words on the relative accuracy and cost of the different methods would also add to the utility of the work.

It follows from the omission of the sextant that there is no reference to hydrographic surveys, or to the location of drainage systems, etc., and the Appendices on Elimination of Local Attraction, Computing Areas by Traversing, Probable Error and Problem in Testing, etc., seem to be out of place, as if they were afterthoughts. Each has its appropriate niche, where it should be placed in future editions.

While the book is nearly all its title claims for it, the addition of a few more chapters on plotting and computations would make it a comprehensive treatise on surveying, and we believe this expansion would prove advantageous to the author, since in its present shape it should be supplemented by personal instructions, or by other books which cover substantially the same ground.

Mechanically, the book is a good piece of work, and typographically attractive, but a little less ink on some of the cuts (pp. 131–132–302) would improve their appearance. The name and reputation of its author is sufficient to guarantee for its large sale, and these comments, it is hoped, may still further extend its usefulness in the near future. H.

The Practical Management of Dynamos and Motors. By Prof. Francis B. Crocker and Dr. Schuyler S. Wheeler. New York: D. Van Nostrand Company. 1892. Cloth, 5 x 7½. 32 pp. Price, $1.

The title of this book expresses clearly the characteristic purpose which the authors had in view. The subject-matter was prepared primarily to assist those in charge of the installation and operation of dynamos and motors, by presenting the essential practical features of the work in clear and concise language, and by having the matter well classified and arranged for ready reference.

The general principles of dynamos and motors are treated briefly in the first two pages, and the remainder of the book is devoted to actual selection, installation, management, testing and general handling of these machines. In this respect this book is unique, and will be very useful to the practical man as well as the student.

Part I is devoted mainly to the essential considerations in selecting dynamos and motors and installing the same; methods of setting them up, making the electrical connections, placing fuses, switches, etc.; starting and stopping the machines, and instructions for running them, coupling them in parallel or series, etc.; and lastly, the testing of dynamos and motors, their adjustment, mechanical condition, electrical resistance, output and input, efficiency, magnetism, etc.

Part II treats of the localization and remedy of troubles in dynamos and motors, and includes the subjects of sparking at the commutator, heating of armature and field-magnets, bearings, noise, speed and failure of dynamo to generate or of motor to start, etc.

Throughout the book the heading of each paragraph is given in bold type, which aids greatly in reference. In Part II the subject of the localization and remedy of trouble is arranged and classified in a very convenient manner. Under each trouble the various causes are mentioned and under each cause the symptom by which it can be recognized and the remedy that should be applied. The words "Cause," "Symptom" and "Remedy" head their respective paragraphs, and are printed in bold type, and altogether this part of the book resembles a veritable *Materia Medica*.

The subject-matter of the book first appeared as a series of articles in the *Electrical Engineer*, of New York, between September, 1891, and May, 1892, and the demand for these articles led the authors to rewrite them for publication in the present form.

Anyone connected with the actual handling of these electrical machines or contemplating doing so, will find it extremely useful to have this little book by his side for reference and study, and students and electricians will find it a good investment as well. H. S. H.

The Alternate Current Transformer in Theory and Practice. By J. A. Fleming, M.A., D.Sc. (Lond.) Vol. II. *The Utilization of Induced Currents.* London: *The Electrician* Printing and Publishing Company, Limited. 1892. Cloth, 5½ x 8½. 594 pp. Price, $5.

The first volume of this valuable book, which appeared in 1890, has become a standard work for study and reference and treated the general subject of induction of electric currents. The second volume, whose appearance has been anxiously awaited, takes up the utilization of induced currents, and, therefore, treats of the practical application and construction of transformers for the conversion and distribution of electrical energy.

The first chapter includes the historical development of the induction coil and transformer, from Henry's researches and Sturgeon's investigations to the present time, and contains many illustrations of early and recent apparatus and interesting results of experiments.

The second chapter goes into the distribution of electrical energy by transformers and explains the various systems and apparatus employed. The systems of Ganz, Westinghouse, Lowrie-Hall, Thomson-Houston, Mordey and Ferranti obviously receive the most attention. A number of plans and elevations of central stations and also switchboard diagrams are given for each system.

The next chapter takes up the general design and equipment of alternate current stations, and considers the boilers, engines, turbines, dynamos, etc., to be used, the selection of units, general arrangements, etc., and the conductors employed. Some attention is also given to the capacity effects, automatic change-over switches, pressure regulation, etc.

The fourth chapter enters into the construction and mode of action of transformers of the present day. The determination of the "transformer indicator diagrams," curves of electro-motive force, curves of magnetic induction and leakage, experiments on iron core losses, etc., are considered in the first part, and it is interesting to note that most of the methods and results described there are those of American investigators. The design of transformers is there treated in considerable detail and finally the various methods of measuring the efficiency of transformers are given.

The last chapter contains a brief description of electric welding and its applications, with illustrations of various welding tranformers, dynamos, etc.

Altogether, this book is the most complete treatment of the subject in print, and the second volume forms an important part of the whole, though it can be used to advantage as a separate volume, since it treats its particular part of the subject in so a complete manner.

Of course, being a pioneer book, there are a number of things that might be criticised, but they will doubtless be remedied in future editions. Typographical and other errors, so numerous in Vol. I, appear occasionally in Vol. II, and the typography and printing are equally poor, if not worse.

H. S. H.

Notes and Examples in Mechanics. With an Appendix on the Graphical Statics of Mechanism. By Irving P. Church, C.E. New York: John Wiley & Sons. 1892. Pp. 118 and 28, vi plates.

The author in his preface states that this forms a companion volume to his *Mechanics of Engineering*, but it could be well used in connection with almost any work on the subject; although one is surprised that so many deficiencies should have been found in the *Mechanics of Engineering*, which by the way is a volume of 800 pages.

The first chapter deals with a proper conception of forces, and while illustrating clearly what the author intends conveying does it in such a way that the conception is limited to forces exerted by or on rigid bodies, either at rest or in motion, and requires a recasting before it can apply to fluids in motion. This chapter closes with an indirect derivation of Simpson's rule. Much less space is devoted to this rule in this and similar books than the subject deserves, and while, if properly used, it is one of the most useful tools the engineer has to work with, it is generally given scant room in our text-books, and its application is almost unknown. This rule gives approximate results in most cases, but in very many it gives exact values, and a reasonable knowledge of the method of using it and its limitations would require much less dependence on reference books for values of quantities in constant use among engineers.

Chapter II treats of the principles relating to non-concurring forces in a plane. In analyzing such forces the diagrams are not well selected. If a body is in equilibrium, any graphic representation of it should reasonably represent equilibrium. The author in his text covers the matter exactly, but the figure represents only two forces which could not possibly be in equilibrium, and it is really important that graphical representations, which are very valuable aids in securing lasting impressions should be so made that the conditions under discussion are accurately set forth.

The use of such terms as "heaviness" of a body, "anti-derivative" and "anti-resultant" are hardly necessary. They convey no meaning which cannot be conveyed in terms in general use. To many of the readers of this review an expression such as "a certain substance has a heaviness of forty," will mean absolutely nothing. The remainder of the chapter is devoted to an analysis of various combinations of rigid bodies at rest acted on by forces. The author calls attention again to the use of such phrases as "balanced forces," "forces in equilibrium," the meanings of which are perfectly clear, but which he thinks are unfortunately worded.

In Chapter III the author deals with the motion of a material point. His definition of acceleration is just as it should be, but his example is decidedly objectionable. He says, "similarly, if at the same instant, the acceleration of the material point is said to be twenty feet per 'square second' (or twenty feet per second, per second'), we mean," etc. The coining of a term as barbarous as "square second" is quite as bad as the using of many of the new terms which simply make one book harder to read than another, and while the author is not the originator of it, it should not be used by anyone, as the same thing can be better expressed otherwise.

It is a pity that space should have been given for the use of such terms as "speed" and "hurry," as units of velocity and acceleration.

The author states the general uselessness of the term momentum and how the use generally made of it to determine accelerating force is superfluous. Nevertheless, it is used by him in cases where the principle of the conservation of momentum is readily applicable. The balance of this chapter is taken up with problems relating to the pendulum in various forms.

Chapter IV is made up of numerical examples on the subjects previously treated of.

Chapter V treats of moment of inertia of plane figures.

The use of unusual terms is to be found here also—not unusual to students of the author's other works—but to engineers and students generally; as for instance, "it will be noticed that the first term, $\frac{1}{12}$ *bt.*^{3} [or local (gravity) moment of inertia] . . . is very small as compared with the second, or 'transferral term' (*bt.* d^2), and '= 129,870,000 *bi.* fiftieths' or '20·77 *bi.* in."

Chapter VI treats of dynamics of a rigid body. Numerous examples are worked out, covering many special applications to machines for utilizing or absorbing energy.

Chapter VII treats of Mechanics of Materials and Graphical Statics, and covers such subjects as I-beams, treated without the use of moment of inertia, Lanza's tests of wooden posts, Pencoyd tests of columns, etc. The Appendix is devoted to notes on the Graphical Statics of Mechanism, and is interesting and valuable.

The volume as a whole is a very valuable one and any one interested in mechanics, who finds that he can follow the author, has a good working knowledge of the principles involved. H. W. S.

A Treatise on Gear Wheels. By George B. Grant. Published by the Author, 1893. Sixth Edition, pp. 103+2.

The fact that this little work is in its sixth edition, speaks strongly of the practical value of the matter contained therein. The reading-matter in the present edition is identical with that in the first edition and has the same defects as to arrangement and want of continuity due to its having been originally printed in a technical journal. The author has added two pages of index which will add greatly to its value as a work of reference.

H. W. S.

ANNUAL REPORT OF THE DIRECTOR OF THE DRAWING SCHOOL OF THE FRANKLIN INSTITUTE FOR THE SESSIONS 1892–93.

The work of the school has been very satisfactory this year, and stands pre-eminent in the department of mechanical drawing. The school adheres rigidly to its special technical lines, and does not profess nor attempt to be a school of art. Its object is to give the greatest amount of instruction that will be of the most value for constructive purposes, and to give this in the most efficient manner; that is to say, with the least consumption of time and money. In order to accomplish this, it has a clearly defined course, the result of years of experience and effort, which commences at the beginning and progresses regularly and logically to the end in view. That the methods employed have been well devised and selected, is shown by the number of young men who have entered this school with no previous knowledge of the subject, and who now hold responsible and valuable positions, due to the training received here, and to the development of tastes and qualifications for this useful and important line of work, which such training has caused.

The value of having a good knowledge of mechanical drawing, lies not merely in the possession of the ability to make such drawings in a manner to be easily and clearly understood, but also in the ability to read and interpret them when made by others. Every mechanic should possess this knowledge, not merely superficially, but thoroughly. His usefulness is greatly increased by it, and his advancement made more certain and rapid. Many excellent workers, possessing superior skill of hand, physical endurance, good judgment, inventive faculties, quick decision, and influence with men, and who would make excellent foremen, have been kept at the bench all their lives, from lack of this knowledge. The number of draughtsmen required to plan and lay out the details of the world's constructive work is comparatively small, but the number of persons who should be able to read and understand these plans, should be limited only by the number of workers themselves, if the most economical results are to be obtained. In this connection, however, I have often observed that those individuals who attend the school, professedly for the purpose of not learning to make drawings, but merely to get a general idea, so as to be able to understand them, and who wish to skip all the elementary and theoretical parts and to go right into working drawings, rarely learn anything at all, simply wasting their time in getting a misconception of what they are doing. The very best way to obtain facility in understanding drawings, is to learn how to make them, and the time and work required to do this are well spent, even if the student never makes another after leaving the school.

The instruction in free-hand drawing is carried on as an adjunct to the constructive drawing, and is intended for an initiation and training in the shape and decoration of constructive details, and not as an introduction to the fine arts.

The instruction in architectural drawing is confined to the plain, everyday requirements of those engaged in building, and does not include a study of the various orders and periods of architecture. It does not profess to educate architects of public buildings, mausoleums and temples, but merely to be of use to the carpenters, plumbers and builders engaged in ordinary work.

As regards the efficiency of the school, the fact should be known, that, although the pupils obtain this useful and important knowledge at a merely nominal charge, yet this is accomplished at no expense to the public at large, and costs the Franklin Institute only the rental of the class rooms.

The Senior Mechanical Class is in charge of Mr. Lucien E. Picolet, the Intermediate Mechanical Classes are in charge of Messrs. George S. Cullen and William H. Sheahan, the Junior Mechanical Classes are in charge of Messrs. George W. Irons and H. Allen Higgins, and the Architectural Class is in charge of Mr. Clement Remington.

The following students are entitled to Honorable Mention:

In the Senior Mechanical Class.

Charles Kolb,
Edward G. Budd,
George W. Hassellund,
Charles McLoughry,
Christian Hagenlocher,
Oscar Mowry,
Eric Ostram.

In the Intermediate Classes.

Emil Snyder,
William Wilkinson,
William C. Gehring,
Zenas Whitemore,
William W. B. Stamm,
Charles Shorb,
William E. Riess,
Samuel R. Preston,
Harry Mehary.

In the Junior Mechanical Classes.

H. P. Rhoads,
Joseph Doebrich,
Miss S. D. Blackwell,
Walter H. Spencer,
George Young,
Rodney Davis,
Roy H. Stacks.

In the Architectural Class.

Benjamin H. Barton,
Jackson Dunlap,
E. D. Salter,
Joseph Sargeant,
Andrew Sauer.

In the Free-Hand Class.

Fritz Ullberg,
H. J. Vollmer,
Norman B. Wheeler.

The following students are awarded scholarships from the B. H. Bartol Fund, entitling them to tickets for the next term, beginning September 19th:

Edward G. Budd,
William Wilkinson,
Emil Snyder,
Benjamin H. Barton,
William C. Gehring,
George Young,
H. P. Rhoads,
Fritz Ullberg.

The following students, having attended a full course of four terms, with satisfactory results, are awarded certificates to that effect:

August Hoffman,
William L. Ambler,
John A. Megenedy,
Charles F. X. Smith,
Malcolm Lovett,
Oscar Mowry,
Joseph Pfluger,
Christian Hagenlocher,
Arthur Bentley,
Austin H. Riegner,
Narciso Battle,
Eric Ostram,
Benjamin H. Barton,
Albert Schoell,
James Patterson,
Howard R. Lamborn,
George Gramlick,
James Walton.

The organization and methods of this School of Constructive Drawing have reached a high degree of excellence, but no pains will be spared to improve them wherever possible in the future, and to maintain our leading position in this line.

William H. Thorne, *Director.*

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, May 17, 1893.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, May 17, 1893

JOSEPH M. WILSON, President, in the chair.

Present, fifty-one members and four visitors.

Additions to membership since last report, seven.

The Actuary reported several resolutions adopted by the Board of Managers at its stated meeting, held May 10th inst., recommending to the Institute that the annual fee from contributing members be raised from $5 to $8; that the annual payment of second-class stockholders be raised from $3 to $6; that the fee for life membership be raised from $50 to $100; and submitting certain changes in the existing by-laws to conform to the foregoing recommendations.

The President directed that the resolutions be posted on the bulletin board in accordance with the by-law pertaining to amendments, in order that the subject might be considered at the next following stated meeting.

The Secretary reported the following action of the Committee on Library, taken at its stated meeting of May 1st inst., viz:

"The Committee on the Library respectfully presents to the Institute a minute upon the death of Mr. Frederick Ransome, which occurred in London, April 19, 1893.

"For many years Mr. Ransome has acted as agent of the committee in London, and as early as September 19, 1877, in recognition of his valuable services, he was elected by the Institute an honorary member, upon the nomination of the Board of Managers.

"Since that time Mr. Ransome has continued his gratuitous services as purchasing agent of the committee, and he has been particularly useful in enabling the committee to complete the collections of various British scientific periodicals by searching out and securing missing back numbers. This service requires continued waiting and watching, and by this labor of love Mr. Ransome aided in completing thirty-one British journals, whose publication began early in the century and still continues.

"Mr. Ransome's services in relation to the publications of the British Patent Office were also extremely valuable.

"The committee desires to place this minute on the records of the Institute, expressing its sense of the loss sustained by the Institute in the death of Mr. Ransome, and it desires also to add the expression of its profound sorrow at the event."

On motion of Mr. Henry R. Heyl, the communication of the committee was ordered to be spread upon the minutes of this meeting.

The Secretary reported a vacancy in the Committee on Science and the Arts caused by the resignation of Mr. S. Lloyd Wiegand. Prof. L. F. Rondinella was elected to fill the vacancy.

Mr. Geo. G. Rockwood, of New York, read a paper on "Photo-ceramics," describing a process of his invention for permanently fixing photographic impressions in colors upon glass. The paper was illustrated by the exhibition of specimens of the new art, which elicited many expressions of admiration. The thanks of the meeting were voted to Mr. Rockwood for his interesting communication. (The paper has been referred for publication.)

Mr. Julius F. Sachse presented a paper descriptive of an improvement in tele-photo lenses devised by Mr. Albert B. Parvin, of Philadelphia. The paper was illustrated by the exhibition of specimens of photographic work executed with the improved lens. (Referred for publication.)

Mr. Robt. B. Haines, Jr., exhibited a number of specimens of his automatic micrometer rolling-mill gauge for measuring hot plates, sheets and bars while in process of rolling. The apparatus shown by Mr. Haines exhibited certain improvements upon the original form of the device shown at the stated meeting of November, 1892. The speaker also made some critical remarks upon the new standard gauge for sheets and plates approved at the last session of Congress.

Under new business, Mr. George V. Cresson was elected as a Trustee of the Elliott Cresson Medal Fund in place of Mr. Samuel Sartain.

The Secretary, in his monthly report, referred to the interesting results obtained by M. Moissan, in recent experiments on the behavior of metallic oxides when subjected to the extremely high temperatures attainable in the electric furnace. He exhibited an interesting product made in a furnace of this kind and which is at present attracting considerable attention on account of its properties as an abrasive material. This product is made by subjecting an intimate mixture of carbon and ground silica for a number of hours to the heat of the electric furnace, the resulting product when freed from intermingled impurities being affirmed to be a compound of carbon and silicon in atomic proportions, corresponding to the formula CSi. This product is crystalline in texture and is extremely hard. It is crushed to powder of various degrees of fineness, and either in the powder form or formed into discs, with a suitable cementing material is used as a substitute for diamond dust, corundum and emery. It is known by the trade name of carborundum.

The Secretary exhibited a specimen of chased aluminum, which had been very successfully electroplated with silver by a process devised by Mr. J. D. Darling, of Philadelphia.

Adjourned. WM. H. WAHL, *Secretary.*

PENNSYLVANIA STATE WEATHER SERVICE,

UNDER THE DIRECTION OF THE FRANKLIN INSTITUTE,

CO-OPERATING WITH THE

UNITED STATES DEPARTMENT OF AGRICULTURE, WEATHER BUREAU.

H. L. BALL, WEATHER BUREAU, OBSERVER IN CHARGE.

MONTHLY WEATHER REVIEW.

FOR APRIL, 1893.

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, April 30, 1893.

GENERAL REMARKS.

With this issue the State Weather Service begins again its monthly review, following the form adopted when the Service was first organized in 1887. The review was regularly issued in printed form until May, 1891, when it was discontinued for want of funds. After that and until the present, the data collected by the observers were published by a duplicating process, which, though laborious and utterly unfitted for that purpose, was the best at hand, and served little more than to preserve the summaries of the observations taken, in the hope that eventually they could be printed in a form suitable to the many purposes for which designed. If possible, the reviews issued by duplicating process will be printed in the usual form.

A series of charts, showing by isothermal lines the normal temperature of each month, will begin with April, and be continued through the year. These isotherms were drawn by an expert, under the direction of the Chief of the United States Weather Bureau, from all available data, extending from the earliest known records down to and including the year 1892.

The normal temperature of Pennsylvania for April is about 48°·0, and the normal precipitation, 3·27 inches. The temperature of the current month was slightly below the normal. The rainfall was unequally distributed, but was above the normal at all the stations.

From January 1, 1893, to April 30, 1893, the deficiency in temperature at Philadelphia was 306°, at Erie 356°, and at Pittsburgh 274°.

For the same period the departure in precipitation was, at Philadelphia, an excess of 1·86, Erie 1·28, and Pittsburgh 1·63 inches.

	Mean Temperature.	*Mean Precipitation. Inches.*
April, 1888, ...	46°·5	2·52
1889, ...	48°·7	4·50
1890, ...	48°·7	3·46
1891, ...	49°·8	2·08
1892, ...	47°·0	2·04
1893, ...	47°·6	4·74

TEMPERATURE.

The mean temperature for April, 1893, was 47°·6, which is 0°·4 below the normal, and 0°·6 above the corresponding month of 1892.

The mean of daily maxima and minima temperatures, 57°·6 and 37°·8, gives an average daily range of 19°·8, and a monthly mean of 47°·7.

Highest monthly mean, 53°·5 at Altoona.

Lowest monthly mean, 40°·1 at Wellsboro.

Highest temperature recorded during the month, 85° on the 8th at Johnstown.

Lowest temperature, 16° on the 16th at Columbus.

Greatest local monthy range, 58° at Hollidaysburg.

Least local monthly range, 38° at Harrisburg.

Greatest daily range, 51° at Hollidaysburg on the 3d.

Least daily range, 1° at Blue Knob on the 7th and at Aqueduct on the 15th and 20th.

BAROMETER.

The mean pressure for the month, 30·04 is about ·04 above the normal. At the United States Weather Bureau Stations the highest observed was 30·51 at Philadelphia on the 6th, and the lowest, 29·40 at Erie on the 1st.

PRECIPITATION.

The average precipitation, 4·74 inches for the month, is an excess of 1·50 inches. The largest totals in inches (including melted snow) were Clarion, 6·91; Confluence, 6·37; Blue Knob and Pottstown, 6·20, and Uniontown, 6·11 inches. The least were Reading, 2·95; New Castle, 3·09; Wilkesbarre, 3·27; Bloomsburg, 3·34, and Altoona, 3·48.

The largest monthly snowfall totals in inches were Le Roy, 7·0; Blue Knob, 6·0; Meadville and Dyberry, 5·0 inches.

WIND AND WEATHER.

The prevailing wind was from the West.

Average number: Rainy days, 14; clear days, 7; fair days, 10; cloudy days, 13.

MISCELLANEOUS PHENOMENA.

Thunder-storms.—Blue Knob, 7th, 8th, 12th, 20th, 29th, 30th; Hollidaysburg, 7th, 20th, 30th; Le Roy, 8th, 20th, 21st; Quakertown, 7th, 8th, 14th;

Johnstown, 7th, 8th, 12th, 20th, 30th ; Emporium, 7th, 8th, 20th ; East Mauch Chunk, 7 ; State College, 7th, 8th, 20th, 30th ; Coatesville, 14th ; Kennett Square, 14th ; Phœnixville, 14th ; Grampian, 20th ; Lock Haven, 20th ; Meadville, 7th, 8th ; Saegertown, 7th, 8th ; Harrisburg, 8th, 20th ; Swarthmore, 14th ; Chambersburg, 7th ; Huntingdon, 7th, 8th ; Kilmer, 7th, 8th, 20th, 21st : Lancaster, 14th, 20th ; New Castle, 13th, 15th, 20th, 30th ; Lebanon, 8th ; Coopersburg, 7th, 8th, 14th ; Smethport, 7th, 8th ; Shippack, 14th ; Aqueduct, 7th, 8th, 17th, 21st, 30th ; Philadelphia, 7th, 14th ; Centennial Avenue, 7th, 14th ; Locust Street, 14th ; Selins Grove, 7th, 8th, 17th, 18th, 20th, 30th ; Somerset, 7th, 8th, 12th, 20th, 29th, 30th ; Wellsboro, 7th, 8th, 17th, 20th ; Easton, 30th ; Lewisburg, 9th, 10th, 17th, 30th ; Columbus, 7th, 8th, 20th, 22d ; Dyberry, 18th ; South Eaton, 8th, 21st York, 14th, 20th.

Hail.—Blue Knob, 7th, 20th, 22d, 30th ; Hollidaysburg, 7th, 20th ; Johnstown, 23d ; Emporium, 7th, 20th ; Kennett Square, 7th ; Grampian, 20th ; Meadville, 7th ; Saegertown, 7th, 8th ; Lancaster, 7th ; Lebanon, 7th ; Girardville, 1st, 23d ; Somerset, 30th ; Wellsboro, 7th ; Dyberry, 8th, 15th, 20th, 23d ; South Eaton, 7th, 20th, 22d ; Eaton, 10th ; York, 7th.

Snow.—Blue Knob, 15th, 17th, 21st, 22d, 23d ; Hollidaysburg, 22d ; Le Roy, 6th, 7th, 10th, 20th, 22d ; Quakertown, 7th, 10th ; Johnstown, 15th, 22d, 23d ; Emporium, 7th, 15th, 22d, 23d ; State College, 7th ; Coatesvillle, 7th ; Grampian, 15th, 22d, 23d ; Lock Haven, 7th ; Bloomsburg, 7th ; Meadville, 15th, 21st, 22d, 23d ; Saegertown, 15th, 22d ; Carlisle, 7th ; Chambersburg, 22d ; Kilmer, 7th ; Lancaster, 7th ; New Castle, 15th, 22d ; Lebanon, 7th ; Drifton, 7th ; Wilkesbarre, 7th ; Philadelphia, Centennial Avenue, 7th ; Girardville, 7th ; Selins Grove, 22d ; Somerset, 22d ; Dyberry, 6th, 7th, 17th, 20th ; Honesdale, 7th, 20th.

Frost.—Pittsburgh, 2d, 15th, 16th, 22d, 23d ; Hollidaysburg, 2d, 3d, 18th, 19th ; Quakertown, 11th, 19th, 22d, 23d, 24th ; Emporium, 2d, 5th, 9th, 16th, 19th, 26th ; East Mauch Chunk, 26th ; State College, 2d, 6th, 18th, 19th ; Coatesville, 24th ; Grampian, 3d, 11th, 18th ; Lock Haven, 16th, 18th, 24th, 26th ; Bloomsburg, 3d ; Meadville, 2d, 5th, 6th, 7th, 9th, 11th, 14th, 15th, 16th, 18th, 19th, 23d ; Saegertown, 2d, 5th, 9th, 11th, 15th, 17th, 18th, 19th, 22d, 24th ; Chambersburg, 2d, 3d, 7th, 16th ; Huntingdon, 1st, 3d, 16th, 18th, 24th : Kilmer, 16th, 18th ; New Castle, 1st, 2d, 3d, 5th, 11th, 15th, 16th, 17th, 18th, 19th, 22d, 23d, 24th ; Lebanon, 18th ; Aqueduct, 18th, 19th, 22d, 24th ; 28th ; Coopersburg, 7th, 26th ; Philadelphia, 24th ; Centennial Avenue, 24th, Girardville, 1st, 3d, 5th, 6th, 7th, 8th, 11th, 12th, 13th, 15th, 16th, 17th, 18th, 19th, 20th, 21st, 22d, 23d, 24th, 26th, 28th ; Columbus, 2d, 5th, 6th, 7th, 9th, 11th, 15th, 16th, 17th, 18th, 19th, 23d, 24th, 26th, 28th ; Easton, 11th, 19th ; York, 16th, 19th, 24th.

Coronæ.—Emporium, 24th, 25th ; Lebanon, 23d, 24th, 27th, 28th ; Dyberry, 24th ; York, 1st.

Solar Halo.—Le Roy, 11th, 13th, 14th ; Saegertown, 1st, 6th ; Harrisburg, 28th ; Philadelphia, 6th, 11th, 17th, 19th ; Centennial Avenue, 6th, 11th ; Wellsboro, 28th ; Lewisburg, 16th, 28th.

Lunar Halo.—Lock Haven, 29th; Meadville, 2d; Carlisle, 24th, 28th Lancaster, 22d, 24th, 28th, 29th; Lebanon, 28th; Philadelphia, 22d; Centennial Avenue, 22d, 24th, 28th; Selins Grove, 21st; Wellsboro, 24th; Dyberry, 24th; York, 24th.

Meteors.—State College, 13th; Meadville, 5th, 8th, 15th, 18th.

Parhelias.—Le Roy, 16th, 28th.

LIST OF DISPLAY STATIONS.

Displayman.	*Station.*
United States Weather Bureau,	Philadelphia.
Pennsylvania Railroad Company,	"
Continental Brewing Company,	"
Reading Railroad Company,	"
Baltimore and Ohio Railroad Company,	"
Morris School,	"
Farmers' Market,	"
J. F. Boyd,	Chambersburg.
Samuel Detrich,	Greencastle.
R. H. Thomas,	Mechanicsburg.
F. E. Holler,	Shippensburg.
J. A. Elliot,	Mansfield.
Chas. Petersen,	Honesdale.
J. R. Raynsford,	Montrose.
Frank Loomis,	Troy.
Reporter Journal,	Towanda.
Monterey Hotel,	Blue Ridge Summit.
Lerch & Rice,	Bethlehem.
H. W. Mullen,	Centre Valley.
G. W. Yost,	Collegeville.
Wm. O. Heinly,	Hamburg.
E. J. Sellers,	Kutztown.
Report Publishing Company,	Lebanon.
J. C. McCloskey,	Lock Haven.
A. Simon's Sons,	Lock Haven.
Knowles Croskey,	Phœnixville.
J. M. Boyer,	Selins Grove.
E. P. Wilbur,	South Bethlehem.
A. H. Potts & Co.,	Parkesburg.
J. R. Wagner,	Drifton.
F. B. Brown,	Pricetown.
Geo. R. Guss,	West Chester.
W. G. Owens,	Lewisburg.
J. B. Patton,	Millville.
F. L. Strowd,	Dallas.
R. M. Tubbs,	Shickshinny.
J. M. Bottomly,	Chester.
A. W. Sims,	Mt. Union.

Displayman.	*Station.*
A. M. Williams,	Uniondale.
J. P. Welsh,	Bloomsburg.
W. N. Hurlbut,	Westfield.
W. M. Berry,	Pittston.
Postmaster,	Jenkintown.
B. W. Dambly,	Skippack.
I. R. Cassel,	North Wales.
R. R. Paxon,	Lahaska.
E. A. Pennock,	Chatham.
John Bowen,	Allentown.
Hanover Silk Company,	Hanover.
Geo. Wheeler,	Doylestown.
A. B. Garth & Co.,	Mill Hall.
H. H. James,	Parsons.
E. E. Cramer,	White Haven.
G. S. Tinsley,	Wrightsville.
Parker & Co.,	Oxford.
G. W. Smith,	Waynesboro.
D. G. Martin,	Martindale.
G. W. Brindle,	Unionville.
S. J. McKay,	Stony Point.
G. W. Lewis & Sons,	Atglen.
C. W. Stine,	Dallastown.
W. N. Wilmerton,	Chester.
Brennan & Davis,	Bradford.
J. H. Apple,	Clarion.
C. L. Peck,	Coudersport.
F. J. Burgoon,	Cresson.
P. S. Weber,	DuBois.
T. B. Lloyd,	Emporium.
S. H. Miller,	Greenville.
T. F. Sloan,	McConnellsburg.
E. W. Merrill,	North East.
F. P. Thompson,	Oil City.
D. Schroy,	Rice's Landing.
H. P. Brown,	Rochester.
J. C. Pearce & Sons,	Saltsburg.
Powell Brothers,	Shadeland.
Armstrong & Brownell,	Smethport.
J. H. Fones,	Tionesta.
C. N. Jeffreys,	Addison.
H. A. Stoke,	Reynoldsville.
H. S. Blachly,	Waynsburg.
L. H. Gabler,	Greensborough.
R. H. Mead,	Wilcox.
A. Logan,	Brockwayville.

Displayman.	*Station.*
A. C. Joy,	Warren.
L. E. Berk,	Venus.
J. L. Hunter,	Knox.
Thomas Lynch,	Scottdale.
Fire-brick Works,	Clearfield.
J. C. Blair Company,	Huntingdon.
M. B. Kingsbury,	Linesville.
Jno. Dauberman,	Centre Hall.
Wm. Finch,	Pittsfield.
C. F. Thayer,	Atlantic.
C. La Rue Munson,	Williamsport.
J. B. Robinson,	Jamestown.
A. M. Treadwell,	New Castle.
J. L. Coffey,	Johnson.
Ajax Iron Works,	Corry.
F. L. Sheppard,	Altoona.
G. W. Klee,	Chambersburg.
United States Weather Bureau,	Erie.
United States Weather Bureau,	Harrisburg.
United States Weather Bureau,	Pittsburgh.

MONTHLY SUMMARY OF REPORTS BY VOLUNTARY OBSERVERS OF THE PENNSYLVANIA STATE WEATHER SERVICE FOR APRIL, 1893.

County.	Station.	Elevation above Sea Level (feet).	Barometer Reduced to Sea Level.			Temperature.																Precipitation.				Number of Days.			Wind.			Observers.
							Maximum.		Minimum.				Daily Range.																Prevailing Direction.			
			Mean.	Highest.	Lowest.	Mean.	Highest.	Date.	Lowest.	Date.	Mean of Maximum.	Mean of Minimum.	Mean.	Greatest.	Date.	Least.	Date.	Relative Humidity.	Dew Point.	Total Inches.	Total Snowfall During Month.	Depth of Snow on Ground at End of Month.	Number of Days Rainfall.	Clear.	Fair.	Cloudy.	7 A. M.	2 P. M.	9 P. M.	
Allegheny,	Pittsburgh, A.	820	30·02	30·31	29·51	51·4	80	8	32	2, 16	60·3	42·5	17·8	37	7	8	14	74·4	42·8	4·94	...	...	20	7	6	17	SE	SE	SE	O. D. Stewart, Weather Bureau.
Berks,	Hamburg,	380	...	...	...	48·3	77	4	29	3	57·9	38·8	19·1	35	8	2	2, 30	...	...	4·53	...	...	10	1	16	13	E	NW	NW	William Sharpe.
Berks,	Reading, A.	280	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2·95	...	...	...	...	...	...	...	...	...	Franklin Yager.
Blair,	Altoona, B.	1,181	...	...	...	53·5	78	9	36	16, 24	62·6	44·4	18·2	31	5	10	26	...	...	3·45	...	...	15	...	...	...	...	...	...	Dr. C. B. Dudley.
Blair,	Blue Knob, A.	2,500	...	...	...	46·2	76	8	28	2, 24	53·1	39·3	13·8	31	5	1	7	...	...	6·20	6·0	...	18	4	10	16	NW	NW	NW	A. H. Boyle.
Blair,	Hollidaysburg,[1]	947	...	...	...	49·8	84	8	26	3	61·3	35·2	26·1	51	3	8	25	...	...	5·22	...	...	14	13	7	10	W	W	W	Prof. J. A. Stewart.
Bradford,	Wysox,[1]	718	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Charles Beecher.
Bradford,	Le Roy,	1,400	...	...	...	42·1	68	4	26	26	51·1	32·9	18·2	31	3	4	10	...	...	4·19	7·0	...	17	7	9	14	SW	SW	SW	G. W. T. Warburton.
Bucks,	Forks of Neshaminy,[1]	304	...	...	...	49·2	...	...	...	...	...	...	...	...	...	...	...	...	...	5·66	...	...	14	8	9	13	W	E	E	J. C. Hilsman.
Bucks,	Quakertown,[1]	536	30·10	30·55	29·67	47·3	76	4	28	3	58·6	37·4	21·2	37	1	7	10	...	...	5·15	...	...	14	9	8	13	NE	NE	NE	J. L. Heacock.
Cambria,	Johnstown, A.	1,184	30·09	30·36	29·53	49·8	85	8	30	16	60·3	39·4	20·9	46	3	6	[illegible], 26	...	...	5·44	...	...	20	3	11	16	S	...	S	E. C. Lorentz.
Cameron,	Emporium, A.	1,050	...	...	...	46·4	73	13	22	1	57·4	35·4	22·0	39	1	7	15, 25	78·7	37·8	4·21	0·5	...	18	5	11	14	SW	...	W	T. B. Lloyd.
Carbon,	E. Mauch Chunk,	550	...	...	...	47·1	76	4	28	3	56·9	36·3	20·6	36	8	4	7, 20	...	...	3·92	1·0	...	15	10	8	12	E	NW	W	F. C. Wintermute.
Centre,	State College[1]— Agricultural Experiment Station,	1,191	30·00	30·39	29·48	46·3	78	8	29	11	56·6	36·7	19·9	41	8	7	20	72·7	37·4	5·13	...	...	16	3	12	15	W	W	W	Prof. Wm. Frear.
Chester,	West Chester,[1]	455	30·05	30·48	29·51	49·3	76	4	32	7	58·7	41·1	17·6	32	1	8	10	69·0	38·5	5·02	...	...	13	10	3	17	NE	W	NW	J. C. Green, D.D.S.
Chester,	Coatesville,[1]	380	...	...	...	49·7	79	4	31	3, 24	61·2	39·1	22·1	37	1	9	10, 30	...	...	5·50	...	...	12	11	7	12	NE	W	E	W. T. Gordon.
Chester,	Kennett Square, A.[2]	275	...	...	...	47·5	...	...	...	...	...	...	...	...	...	...	...	...	...	4·55	...	...	12	9	7	14	E	...	SW	B. P. Kirk.
Chester,	Phœnixville, A.	190	30·06	30·47	29·65	50·7	77	4	33	7	60·1	41·2	18·9	33	1, 8	8	14	78·3	43·0	5·24	...	...	13	5	10	15	SE	...	SE	Knowles Croskey.
Chester,	Westtown,	350	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Harry Alger.
Clearfield,	Grampian,*[1]	1,450	...	...	...	44·2	70	4, 29	28	11	52·4	37·2	15·2	32	3	2	20	...	...	4·89	...	...	16	4	11	15	W	W	W	Nathan Moore.
Clinton,	Lock Haven,[1]	560	...	...	...	47·5	79	27	27	25	59·5	35·6	23·9	43	3	2	10	...	...	4·72	1·0	...	15	14	5	11	W	W	W	Prof. J. A. Robb.
Columbia,	Bloomsburg, A— State Normal School,	500	29·93	30·31	29·48	48·0	75	4	32	5, 11	57·3	38·6	18·7	37	28	5	15	70·4	36·9	3·34	0·5		14	6	12	12	E	...	W	Prof. J. G. Cope.
Crawford,	Meadville— Divinity Hall,[1]	1,200	...	...	...	45·1	75	8	23	16	57·0	34·5	22·5	40	3	8	15	76·5	43·3	5·30	5·0	...	18	1	9	20	SW	SW	SE	Chas. Graves.
Crawford,	Saegertown, A.	1,200	...	...	...	45·2	74	8	24	17	55·8	34·6	21·2	38	5	7	22	...	...	4·43	3·0	...	16	2	12	16	SE		SW	J. G. Ap[illegible]e.
Cumberland,	Carlisle,[1]	480	...	...	...	47·3	78	4	32	3, 16	59·9	38·5	21·4	41	28	7	10, 12	...	...	3·71	...		14	9	10	11	W	SW	S	J. E. Pague.
Dauphin,	Harrisburg, A.	361	30·06	30·44	29·57	48·6	71	9	33	7	56·1	41·1	15·0	32	8	2	10	77·3	40·8	3·67	...	...	14	8	10	12	E	E	E	F. Ridgway, Weather Bureau.
Delaware,	Swarthmore, A— Swarthmore College,	190	30·03	30·34	29·56	48·9	76	4	35	7	60·1	43·3	16·8	32	1	3	10	78·0	37·0	5·51	...	...	11	4	15	11	E	...	E	Prof. Susan J. Cunningham.
Erie,	Edinboro,*[1]	1,400	...	...	...	42·5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	C. F. Sweet.
Erie,	Erie, A.	681	29·99	30·35	29·40	44·0	76	8	25	21	53·0	36·0	17·0	36	8	4	14	75·0	35·0	3·67	...	...	18	4	14	12	NE	NE	NE	P. Wood, Weather Bureau.
Fayette,	Uniontown,[1]	1,000	...	...	...	51·8	83	8	29	16	59·3	43·8	15·5	34	3	4	6, 26	...	...	6·11	...	...	17	7	15	5	SW	SW	SW	Wm. Hunt.
Franklin,	Chambersburg,[2]	618	...	...	...	49·6	...	...	...	...	...	...	...	...	...	...	...	...	...	4·40	...	...	12	13	3	14	W	...	W	G. W. Ludwig.
Fulton,	McConnellsburg,[1]	875	...	...	...	49·7	84	8	30	3, 18	60·9	38·0	22·9	46	8	6	20	71·7	41·0	4·61	...	...	14	8	10	12	W	...	...	T. F. Sloan.
Huntingdon,	Huntingdon, A— The Normal College,	650	...	...	...	49·2	82	8	27	3	61·8	36·7	25·1	46	3	9	25, 26	...	...	4·61	...	...	13		10	11	W	...	W	Prof. W. J. Swigart.
Indiana,	Indiana— State Normal School,	1,350	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Prof. S. C. Schmucker.
Juniata,	Kilmer,[3]	475	...	...	...	51·2	76	4	35	7	...	...	...	...	...	...	...	...	...	5·34	...	...	17	2	14	14	E	E	E	R. J. Mickey.
Lancaster,	Lancaster, A— Franklin and Marshall College,	413	30·06	30·44	29·26	49·9	77	8	32	7	58·4	40·5	17·9	37	1	4	26	76·0	43·3	5·07	...	...	11	11	7	12	NE	...	NW	W. E. Bushong.
Lawrence,	New Castle,[1]	932	...	...	...	50·7	78	8	24	16	58·7	35·8	22·9	45	5	6	14	...	...	3·09	0·7	...	13	3	8	19	SE	E	SE	Wm. T. Butz.
Lebanon,	Lebanon, A.	458	30·04	30·45	29·55	48·1	77	4	30	23	58·3	37·8	20·5	36	28	5	12	78·0	39·5	3·67	0·1	...	15	11	7	12	NE	...	NE	G. W. Hayes, C. E.
Lehigh,	Coopersburg,[1]	520	...	...	...	47·7	72	1	30	3	57·7	39·0	18·7	33	1, 3	5	10	...	...	4·07	...	...	16	8	8	14	NW	NW	NE	Dr. M. H. Boye.
Luzerne,	Drifton (24 days), A.	1,683	30·00	30·33	29·61	43·7	72	4, 8	24	7	55·1	32·3	22·8	41	8	6	21	83·0	41·0	4·63	1·5	...	10	4	10	10	...	...	...	J. R. Wagner.
Luzerne,	Wilkes-Barre, A.	575	...	...	...	49·0	77	4	28	3	62·4	35·6	26·8	39	3	8	15	...	...	3·27	1·3	...	11	13	5	12	W	...	NW	A. W. Betterly.
McKean,	Smethport (25 days), A.	1,500	...	...	...	42·4	72	13	18	11	53·8	31·0	22·8	42	8	4	15	...	...	4·60	...	...	14	5	9	16	SE	...	NW	Armstrong & Browne.
Montgomery,	Pottstown,	150	...	...	...	51·1	76	1	35	3	59·3	43·0	16·3	33	1	2	20	71·4	40·0	6·20	...	...	12	15	6	9	NE	W	S	Charles Moore, D.D.S.
Montgomery,	Skippack, A (23 days),	...	...	...	...	49·0	77	2, 4	30	3, 7	59·7	38·3	21·4	39	3	3	10	...	...	...	...	...	...	11	4	8	W	...	W	B. W. Dambly.
Northampton,	Easton— Lafayette College,	325	...	...	...	47·1	73	4	31	3	56·9	38·2	18·7	33	4	6	7	...	...	3·86	...	...	11	...	...	...	...	...	...	J. W. Moore.
Perry,	Aqueduct, Logania,*	367	...	...	...	50·5	76	4, 8	31	24	59·4	42·0	17·4	37	28	1	15, 20	...	...	4·13	...	...	17	8	9	13	...	...	...	Richard Ca[illegible]
Philadelphia,	U. S. Weather Bureau, A.	117	30·06	30·50	29·57	50·8	75	4	34	7	58·9	42·8	16·1	31	1	3	20	70·1	39·4	4·47	...	...	15	6	10	14	NE	NE	NE	L. M. Dey, Weather Bureau.
Philadelphia,	1529 Centennial Avenue, A.	120	30·06	30·51	29·58	51·7	76	4	34	7	60·5	42·9	17·6	30	1	11	10, 19	70·8	39·4	5·50	...	...	15	8	10	12	NE	...	S	John Comly.
Philadelphia,	2011 Locust Street, A.	...	...	...	...	51·3	78	29	34	7	60·7	42·0	18·7	33	1	8	20	...	...	5·71	...	...	15	5	12	13	E	...	E	Ralph L. Pa[illegible]ck.
Pike,	Blooming Grove,*	...	...	...	...	43·5	...	...	...	...	...	...	...	...	...	...	...	...	...	3·71	...	...	8	...	...	...	...	...	...	John Grathw[illegible]
Schuylkill,	Girardville,	1,000	30·00	30·34	29·48	46·2	73	4	31	3	56·8	36·2	20·6	36	8	7	15	...	...	3·58	0·2	...	13	12	11	7	E	W	W	E. C. Wagner.
Snyder,	Selins Grove, A.	455	30·07	30·42	29·70	49·3	74	18, 28	30	24	61·3	37·4	23·9	36	8	8	7	86·1	42·5	4·64	...		16	0	16	14	SW	...	SW	J. M. Boyer.
Somerset,	Somerset,[1]	2,250	...	...	...	44·4	80	3, 8	27	16	56·3	36·6	21·7	48	3	5	26	75·6	42·5	5·46	1·0	...	15	0	8	22	SW	SW	SW	W. M. Schrock.
Tioga,	Wellsboro,*	1,327	...	...	...	40·1	68	13	25	19	49·4	33·1	16·3	35	28	2	12, 20	...	...	5·38	...	...	10	5	6	19	N., NW	...	...	H. D. Dem[illegible]
Union,	Lewisburg, A.	450	30·03	30·34	29·25	47·2	78	4	28	7	57·9	36·5	21·4	42	28	7	12	...	...	4·62	...	...	18	9	7	14	SW	...	S	Prof. W. G. Owens.
Warren,	Columbus,	1,410	...	...	...	44·1	73	3	16	16	54·0	34·0	20·0	40	16	4	14, 22	63·0	29·0	5·25	4·0	...	16	5	13	12	SW	SW	SW	Wm. Loveland.
Wayne,	Dyberry,	1,100	...	...	...	41·8	63	4	22	3, 26	51·3	32·9	18·4	35	3	6	7, 12	...	...	3·65	5·0	...	12	3	18	9	NW	NW	W	Theodore Day.
Wayne,	Honesdale,	1,000	...	...	...	43·0	68	4	25	26	52·2	33·9	18·3	30	3, 28	3	20	...	...	3·89	4·0	...	16	...	...	...	...	...	...	John Torrey.
Wayne,	Salem Corners (Hamlinton),	1,600	...	...	...	41·7	67	30	28	7	49·7	35·3	14·4	27	24	2	29	...	...	4·45	...	...	17	3	14	13	NW	NW	NW	T. B. Orchard, M. D.
Westmoreland,	(Tunnel Reservoir) Lycippus,*	1,420	...	...	...	50·7		...	...	...	...	...	...	...	...	...	...	...	...	5·87	...	...	14	...	...	...	...	...	...	Murray Forbes.
Westmoreland,	Ligonier (25 days),	1,750	...	...	...	47·5	83	8	27	10	59·2	36·5	22·7	41	7	4	15	...	...	5·52	...	...	17	6	9	10	...	...		J. T. Ambrose.
Wyoming,	South Eaton, A.	660	...	...	...	46·1	74	4	28	7, 19	56·2	36·0	20·2	34	28	6	12	...	...	3·53	...	...	10	8	9	13	NW	...	NW	R. M. Hall.
York,	York, A.	385	30·00	30·38	29·52	50·4	81	8	30	24	60·8	40·0	20·8	39	8	5	20	84·1	46·9	4·37	...	...	14	8	10	12	NW	...	NW	Mrs. L. H. Grenewald.

A, Observations taken at 8 A. M. and 8 P. M. B, Observations taken at 12 Noon. * Extremes from dry thermometers. [1] Mean temperatures, 7 + 2 + 9 + 9 ÷ 4. [2] Mean of 8 + 8 ÷ 2. [3] Mean of 7 + 7 ÷ 2. Absence of numerals indicates that mean of temperature is from maximum and minimum readings.

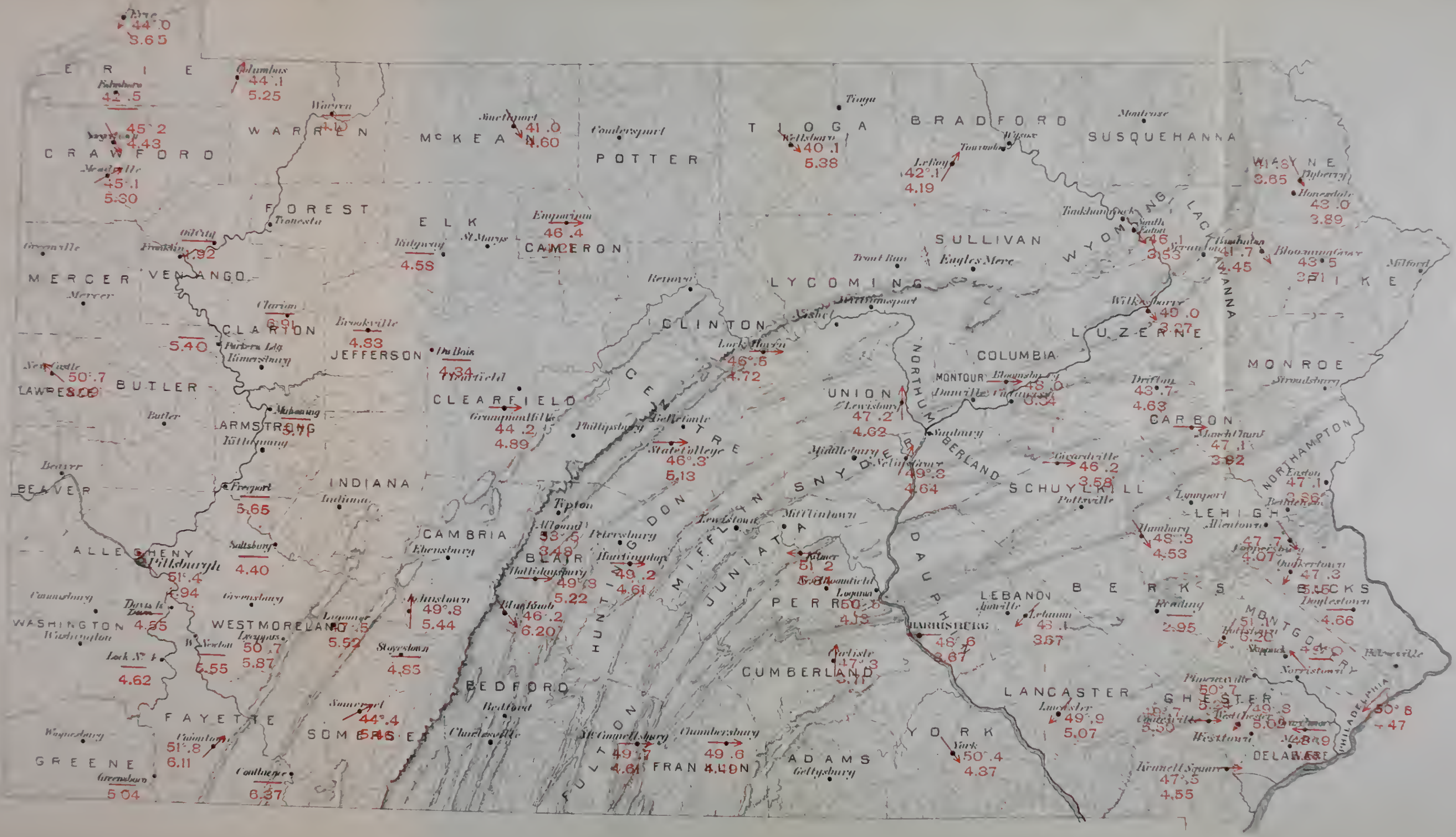
PRECIPITATION DURING APRIL, 1893.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total.
Delaware Basin.																																
Blooming Grove,							·80			·26		·05			·73			·10			1·55		·10					·12				3·71
Browers Lock,								·41			1·02		·07		1·40					·70	·24	·07	·08	·06	·19	·56				·04		4·84
Coatesville,							·26			1·15		·17		·96	·54		·20		·03	1·07	·21				·24		·60		·07			5·50
Coopersburg,							·54	·03		·37		·05	·04	·56	·45		·10			1·06	·15	·02	·01		·15		·47		·03	·04		4·07
Doylestown,						·02	·50	·02		·53		·03		1·20	·48					1·27	·13				·05		·36					4·66
Dyberry,				·10			·43	·67		·10			·10	·30	·35					1·10	·12	·10	·05				·23					3·65
Easton,				·01				·77			·36			·05	·70		·13			1·05	·01				·14		·39			·25		3·86
Forks of Neshaminy,						·03	·62	·08		·73		·03	·01	1·10	·48		·14			1·26	·25				·19		·72		·02			5·66
Frederick,						·02	·41	·03		·59	·03	·08		·90	·48					·58	·16				·14		·53					4·01
Hamburg,							·92	·05		·54		·40	·20	·39	·51					1·11							·29		·12			4·53
Honesdale,				·06		·01	·52	·57		·21			·03	·30	·37		·05			1·32	·09	·02			·03		·20		·01	·10		3·89
Kennett Square,							·25	·03		·42		·15	·03	·48	1·06			·07		·96	·15				·25		·70					4·55
Lansdale,							·55			·76	·01	·25		1·43	·41					·57	·05				·15	·38	·01			·02		4·59
Mauch Chunk,							·73		·07	·30	·05		·23	·09	·53		·13			·83	·52	·06	·03		·10		·17		·08			3·92
[illegible]							·50	·10		·42		·05		1·00	·61		·07	·07	·02	·90	·31	·02			·05		·60			·08		4·80
Philadelphia, a*							·33			·88	·01	·04	·02	·35	·79		·01	·05		·83	·08				·22		·83		·01	·02		4·47
Philadelphia, b							·40			1·03	·02	·07	·01	·47	·89		·01	·06		1·30	·06				·27		·88		·02	·01		5·50
Philadelphia, c,							·36			·98	·02	·07	·01	·51	·93		·05	·02		1·54	·04				·25		·87		·03	·03		5·71
[illegible]							·39	·04		·35	·03	·05	·01	1·30	·51					·83	·25				·23		·63			·02		5·24
[illegible] Pleasant,				·66	·05					·37		·06		1·00	·46					1·29	·16						·60	·10		·05		4·80
[illegible]						·03	·47	·05		·75		·12		1·72	·48					1·25	·33				·18		·60			·22		6·20
Quakertown,							·66	·15		·23		·08	·02	·96	·51		·05		·03	1·34	·27				·19		·58			·08		5·15
Reading,	·01					·01	·15	·01		·45		·11	·01	·42	·45		·01	·01		·66	·22	·01			·15		·25	·01		·01		2·95
Salem Corners,						·03	·43	·05	·22	·05	·15		·06		·75	·05		·18		1·59	·57	·09	·07	·02			·10	·02	·02			4·45
Seisholtzville,							·44	·14		·48	·06	·07		·43	·40					1·16	·29					·60				·13		4·20
Smith's Corner,							·77	·05	·08	·43	·02	·05	·04	·91	·41		·15			1·26	·25				·16		·50					5·08
Swarthmore,							·50	·50		·50		·50		·95	·05					1·32					·23		·90		·04	·02		5·51
West Chester,							·23	·01		1·13		·14		·84	·65			·02	·03	·89	·17				·29		·59		·03			5·02
Westtown,																																
Susquehanna Basin.																																
Altoona,							·25		·06	·40	·03	·36	·13	·05	·54				·02	·32	·72	·17			·05		·22		·16			3·48
Aqueduct,							·35	·15		·60		·25	·04	·25	·30		·05		·05	1·20	·15	·06			·09	·18	·03		·13	·25		4·13
Bloomsburg,							·54	·06		·41		·04	·09	·33	·35		·07			·73	·24	·02			·12		·30			·04		3·34
Blue Knob,	·29			·03		·01	·37	·01		·56		·67	·05	·40						1·64	·30	·40	·20		·30	·02	·18		·30	·67		6·20
Carlisle,							·22	·03		·55	·22	·54	·06	·05	·42					·62	·58				·03		·32		·06	·01		3·71
Drifton,		*							*	·76	·89		·30		·56	*		·37		·39	·75	·13	*	·13			·35			*		4·63
Emporium,	·14			·13			·73	·20		·29		·18	·08	·39	·32				·10	·45	·62	·04	·02		·11		·15		·04	·22		4·21
Girardville,							·46			·52		·10	·09	·22	·36		·06			·98		·06			·08		·04		·28	·33		3·58
Grampian,	·24						·57			·40		·45	·06	·57	·08				·12	·33	·34	·58	·02		·18		·32		·04	·59		4·89
Harrisburg †							·27	·04	·08	·69	·04	·39	·07	·28	·23					·80	·46				·16		·14			·07		3·67
Hollidaysburg,	·05						·28			·66		·70		·42	·23				·15	1·26	·40	·09			·16		·23		·16	·43		5·22
Huntingdon,				·01			·40			·59	·03	·66		·31	·23					·70	·75	·07					·25		·32	·29		4·61
Kilmer,				·01			·41	·17		·71		·44	·07	·22	·17				·12	1·90	·29	·03			·08	·02	·15		·30	·25		5·34
Lancaster,							·18	·02		1·05	·25	·22		·55	1·22					·80	·44				·21		·13					5·07
Lebanon,							·25		·06	·58	·01	·26	·04	·31	·36		·25			·83	·31				·17		·19		·04	·01		3·67
Le Roy,	·01			·12		·06	·49	·20		·34		·03		·10	·60		·05			·97	·93	·06	·03		·03				·01	·16		4·19
Lewisburg,		·21		·01			·78	·24		·45		·20		·45	·31		·06	·08	·12	·73	·83	·05			·07		·08		·05	·10		4·62
Lock Haven,	·10			·10			·60	·14		·60		·38	·03	·70					·06	·52	·75	·08			·18		·08			·40		4·72
Selins Grove,							·30	·05		·12	·03	·12	·09	·30	·29		1·05	·02	·01	·61	·74	·13							·37	·41		4·64
South Easton,				·02			·27	·45		·23	·03			·32	·29		·06			1·49	·37											3·53
State College,	·06			·08			·51	·16		·60		·58	·03	·58	·33				·12	·62	·58				·09		·17		·07	·55		5·13
Wellsboro,				·02			·12	·37		·54				·75	·45		·05			1·78	1·20									·10		5·38
Wilkes-Barre,							·70			·26			·03	·15	·69					·93	·32		·03		·01	·03	·12					3·27
Wysox,																																
York,							·16			1·16	·02	·30	·02	·42	·53		·07		·02	·89	·26				·20		·28		·04	*		4·37

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total.
Ohio Basin.																																
Brookville,		·32		·27			·18	·22	·08	·04	·06	·16	·31		·73	·09				·42	1·13	·11	·14		·09	·06	·13			·23		[illegible]
Clarion,		·45		·35			·45	·31	·09	·05	·20	·15	·20		·79	·05		·05		·60	1·85	·12	·06	·07	·11	·14	·50	·02		[illegible]		[illegible]
Columbus,	·42						·68	·46		·05		·12		·22	·36		·04		·15	·65	·65	·15		·19			[illegible]		·14	[illegible]		[illegible]
Confluence,		·20		·20		·12			·03	·57	·20	·42	·17		·35			·03	·01	·22	2·21	·26	·18		·03	·22	[illegible]		[illegible]			[illegible]
Davis Island Dam,		·08		·23			·15	·15		·37	·15	·44	·17		·38		·02	·02		·14	·72	·09	·03		·10	[illegible]	[illegible]		·50	[illegible]		[illegible]
DuBois,				·23			·45	·12		·24		·30	·12	·20	·03	·57				·50	·78	·14	·29	·03	·09		·13					[illegible]
Freeport,		·12		·23			·15	·18	·02	·33	·22	·50	·22		·56			·02		·26	1·45	·21	·13		·12	·15	·40		[illegible]	[illegible]		[illegible]
Greensboro,		·15		·34		·03			·05	·50	·10	·25	·23		·77				·05		1·20	·10	·20		·05	·18	·20		[illegible]	[illegible]		[illegible]
Immel Reservoir,				·15			·21	·14			·54	·98	·10		·68						1·00	·09	·12		[illegible]		·50		[illegible]	[illegible]		[illegible]
Indiana,																																
Johnstown,	·12			·02			·38	·02		·56		·64	·13	·48	·23		·02		·03	·82	·45	·10	·10		·19	·12	·39		·20	·44		[illegible]
Ligonier,	*	*	*	·11			·23	·11		·54		·60		·88	·02		·02		·10	1·24	·13	·10	·04		·25	·32			[illegible]	·20		[illegible]
Lock No. 4,		·12		·22				·13	·02	·23	·22	·44	·09		·78		·01	·02		·01	·94	·10	·05		·05	·24	·26		·54	[illegible]		[illegible]
Mahoning,		·30		·36			·23	·23		·24	·16	·23	·16		·66					·67	1·63	·13	·03		[illegible]	·03	·38		[illegible]	[illegible]		[illegible]
Meadville,	·39			·13			·99	·58		·15		·20		·18	·48		·12		·13	·11	·43		·06		·13	·13	·05		[illegible]	[illegible]		[illegible]
New Castle,	·46			·50			·22			·14		·38	·14	·20	·22					·30	·63	·02			·13		[illegible]		[illegible]	[illegible]		[illegible]
Oil City,		·33		·10			·42	·33	·30		·06	·23	·10		·83	·06		·05		·39	·93		·09		·17		·33		[illegible]	[illegible]		[illegible]
Parker's Landing,		·35		·49			·25	·23		·12	·13	·27	·12		·51	·09		[illegible]		·52	1·30	·06	·05	·04	·14	·04	[illegible]			[illegible]		[illegible]
Pittsburg,†	·10			·24			·33	·01		·51	·03	·50	·06	·41	·13		·08		·09	·74	·20	·08			·25	·18	[illegible]		[illegible]	[illegible]		[illegible]
Ridgway,		·45				·66				·17	·12		·64					·51	·95	·11	[illegible]		·20		[illegible]		·03	·18	[illegible]			[illegible]
Saegertown,	·57			·13			·76	·46	·05		·30		·07	·48						·54	·26	·01	·02		[illegible]		·45		[illegible]	·05		[illegible]
Saltsburg,		·09		·20			·15	·12	·01	·30	·25	·18	·17		·65	·02				·07	1·03	·05	·05		·08	[illegible]	·24		[illegible]			[illegible]
Smethport,	·25						·50	·40		·25		·25	·20	·50	·20					·50	[illegible]	·25			·10		·15			[illegible]		[illegible]
Somerset,								·40		·82		·68		·55	·15		·10		·05	·42	[illegible]	·10	·14		·45	·30			[illegible]	[illegible]		[illegible]
Stoyestown,	·07		·02	·03					·54	·45	·26	·40	·21							·74	[illegible]	·28	[illegible]			·05	[illegible]	·39		[illegible]		[illegible]
Uniontown,	·11			·55		·51	·14	·12		·63		·32	·17	·72				·03		1·14	·08	[illegible]			[illegible]	[illegible]			[illegible]	[illegible]		[illegible]
Warren,		·40		·02	·01		·00	·10	·54		·15	·07	·04		·45	·01				·40	1·19	·03			·19	[illegible]	[illegible]		[illegible]	[illegible]		[illegible]
West Newton,		·06		·15			·04	·15	·07	·29	·23	·50	·10		·75			·05		·05	1·54	·06	·15		[illegible]	·19	[illegible]		[illegible]	·25		[illegible]
Potomac Basin.																																
Chambersburg,							·15			·98		·53			·38		·06			[illegible]	·08	·10			[illegible]		·22		[illegible]			[illegible]
McConnellsburg,							·15	·20		1·01		·74		·30	·10					1·12	·33	·07			[illegible]	·16	·13		[illegible]	[illegible]		[illegible]
Lake Basin.																																
Erie,†	·28			·01			·10	·30				·11		·28	·70		·02		·04	·33	·20	·05	[illegible]		·36	[illegible]	·14		[illegible]	·60		[illegible]

† U. S. Weather Bureau Stations. * Missing.

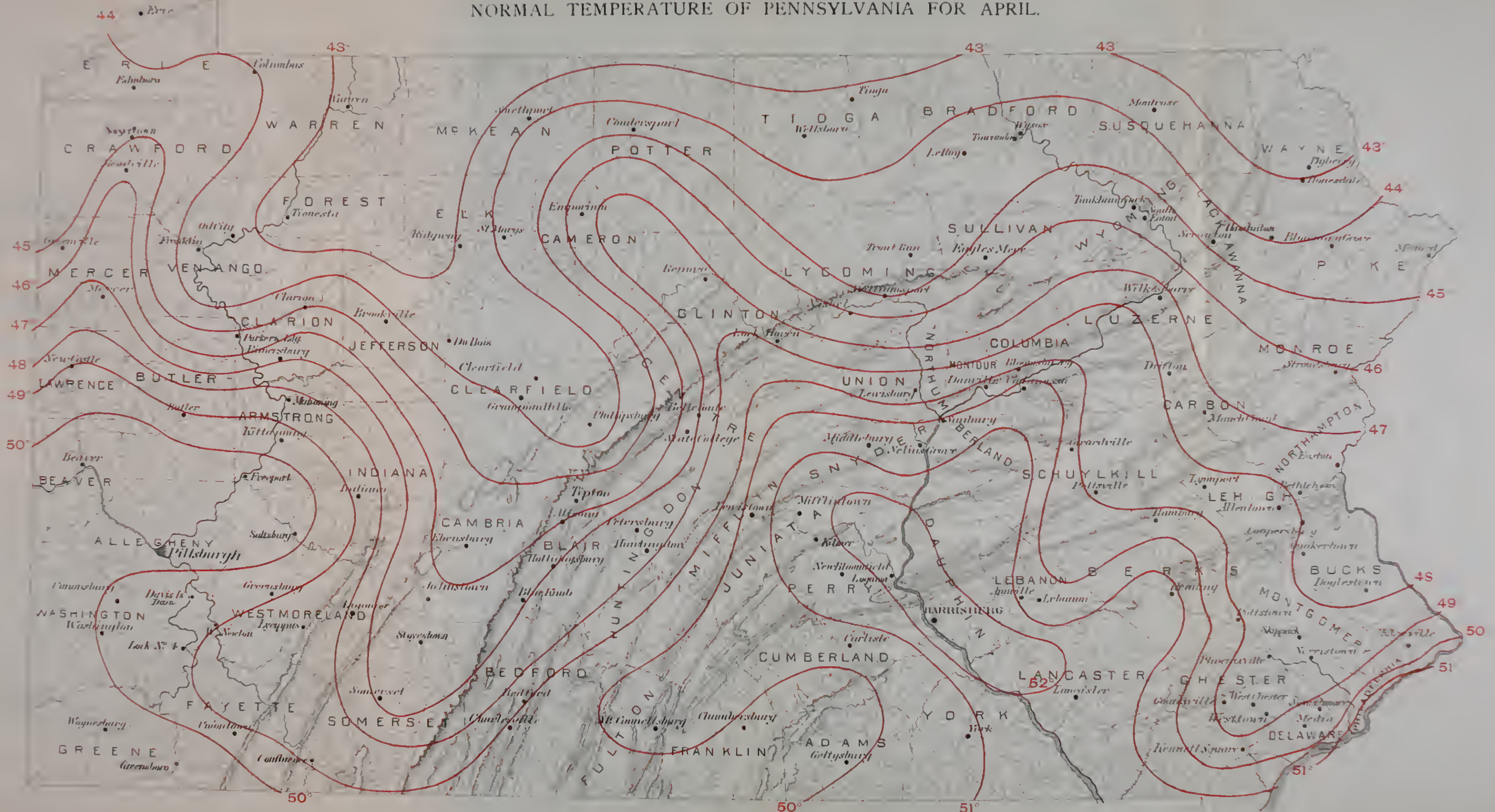
MEAN TEMPERATURE, RAINFALL AND PREVAILING WIND DIRECTION FOR APRIL. 1893



ISOTHERMAL LINES,

SHOWING THE

NORMAL TEMPERATURE OF PENNSYLVANIA FOR APRIL.



PENNSYLVANIA STATE WEATHER SERVICE,

UNDER THE DIRECTION OF THE FRANKLIN INSTITUTE,

CO-OPERATING WITH THE

UNITED STATES DEPARTMENT OF AGRICULTURE, WEATHER BUREAU.

H. L. BALL, WEATHER BUREAU, OBSERVER IN CHARGE.

MONTHLY WEATHER REVIEW.

FOR MAY, 1893.

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, May 31, 1893.

GENERAL REMARKS.

The normal temperature for May is about 59°·3, and the normal precipitation, 4·09 inches. The following tables will show the departures of both temperature and rainfall during the month of May since the State Service has been in operation.

During the first and second decade the weather was cool, the minimum temperatures nearly all occurred during the first ten days; and at most stations in the mountains and in the northern counties, the mercury fell to and below the freezing point. More or less heavy frost occurred, but no great damage was reported. The warmest days were the 22d and 23d.

The rainfall was excessive at all stations and was pretty evenly distributed, except in the extreme northwestern and southeastern counties. In the former, exceedingly heavy rains occurred on the 16th; in the latter, the total rainfall was lighter than in any other part of the State. Following are the dates on which excessive precipitation occurred (one inch in one hour or two and one-half in twenty-four hours):

Drifton, 3·10 inches, 24 hours, 4th.
Lancaster, 3·40 inches, 24 hours, 4th.
Lebanon, 3·01 inches, 24 hours, 4th.
Le Roy, 3·16 inches, 24 hours, 4th
Selins Grove, 3·57 inches, 24 hours, 4th.
Erie, 3·68 iuches, 24 hours, 16th.
Meadville, 3·32 inches, 24 hours, 16th.
Saegertown, 3·20 inches, 24 hours, 16th.
Dyberry, 1·25 inches, 30 minutes, 23d.

The heaviest hail storm ever experienced, in that vicinity, occurred at Pittsburgh on the 20th, from 3.45 to 3.50 P. M. Hailstones, irregular in form; largest, size of a hen's egg; average, about one inch in diameter. Great damage was done to property in the city, apparently the storm being heaviest there. No serious injury to crops was reported.

From January 1, 1893, to May 31, 1893, the deficiency in temperature at Philadelphia was 353°, at Erie 408°, and at Pittsburgh 359°.

For the same period the excess in precipitation at Philadelphia was 1·81, at Erie 5·76, and at Pittsburgh 2·76 inches.

	Mean Temperature.	*Mean Precipitation. Inches.*
May, 1888, ...	57°·6	4·24
1889, ...	62°·0	5·91
1890, ...	58°·8	6·71
1891, ...	57°·5	2·12
1892, ...	59°·5	5·70
1893, ...	58°·0	5·54

TEMPERATURE.

The mean temperature for May, 1893, was 58°·0, which is about 1°·3 below the normal, and 1°·5 below the corresponding month of 1892.

The mean of daily maxima and minima temperatures, 68°·8 and 47°·0, gives an average daily range of 21°·8, and a monthly mean of 57°·9.

Highest monthly mean, 65°·4 at Kilmer.

Lowest monthly mean, 50°·9 at Wellsboro.

Highest temperature recorded during the month, 93°·0 on the 23d at Kilmer.

Lowest temperature, 26°·0 on the 8th at Wellsboro.

Greatest local monthy range, 60° at Hollidaysburg.

Least local monthly range, 44° at West Chester.

Greatest daily range, 57° at Hollidaysburg on the 20th.

Least daily range, 2° at Aqueduct on the 17th and Salem Corners on the 4th.

BAROMETER.

The mean pressure for the month, 29·91 is about ·09 below the normal. At the United States Weather Bureau Stations the highest observed was 30·39 at Harrisburg on the 10th, and the lowest, 29·34 at Erie on the 16th.

PRECIPITATION.

The average precipitation, 5·54 inches for the month, is an excess of about one and one-half inches. The largest totals in inches (including melted snow) were Blue Knob, 9·20; Drifton, 8·94; Saegertown, 8·89; and Girardville, 8·51. The least were Philadelphia (Weather Bureau) 2·92; Philadelphia (Centennial Avenue), 3·12; Westtown, 3·15, and Philadelphia (Locust Street) 13·37 inches.

WIND AND WEATHER.

The prevailing wind was from the Northwest.

Average number: Rainy days, 12; clear days, 11; fair days, 8; cloudy days, 12.

MISCELLANEOUS PHENOMENA.

Thunder-storms.—Blue Knob, 5th, 12th, 13th, 20th, 23d; Hollidaysburg, 1st, 12th, 20th, 31st; Le Roy, 23d; Quakertown, 1st, 23d; Johnstown, 1st, 5th, 12th, 20th, 31st; Emporium, 23d; East Mauch Chunk, 16; State College, 1st, 20th, 23d, 31st; Coatesville, 5th, 23d; Kennett Square, 5th, 21st, 23d; Phœnixville, 23d; Grampian, 23d; Lock Haven, 20th, 23d, 31st; Bloomsburg, 1st; Meadville, 1st, 15th, 20th, 31st; Carlisle, 5th, 20th, 23d; Edinboro, 12th, 15th, 20th, 28th, 31st; Chambersburg, 2d, 5th, 13th, 20th, 23d; Huntingdon, 1st, 5th, 20th, 31st; Kilmer, 1st, 5th, 20th, 23d, 31st; Lancaster, 23d; Lebanon, 1st, 13th, 20th, 23d; Coopersburg, 2d; Wilkes-Barre, 1st, 23d; Smethport, 12th, 20th; Easton, 10th, 14th, 23d; Aqueduct, 1st, 5th, 20th, 23d, 31st; Philadelphia, 23d; Centennial Avenue, 5th, 16th, 23d; Locust Street, 21st, 23d; Girardville, 3d, 23d; Selins Grove, 5th, 31st; Somerset, 1st, 5th, 12th, 17th, 20th, 21st, 23d, 31st; Wellsboro, 23d, 31st; Lewisburg, 1st, 23d, 30th, 31st; Columbus, 15th, 23d, 31st; Dyberry, 23d, 30th, 31st; Salem Corners, 1st, 24th; Ligonier, 20th; South Eaton, 22d, 30th, 31st; York, 5th, 23d.

Hail.—Blue Knob, 4th; Le Roy, 23d; Edinboro, 15th; Huntingdon, 13th, 31st; Somerset, 5th, 31st; Lewisburg, 23d; Ligonier, 20th.

Snow.—Blue Knob, 4th.

Frost.—Blue Knob, 7th; Hollidaysburg, 7th, 8th, 18th, 19th, 20th; Johnstown, 7th, 8th, 19th, 20th; Emporium, 8th, 9th, 10th, 19th, 20th, 22d; State College, 8th; Coatesville, 8th, 9th, 20th; Kennett Square, 8th; Lock Haven, 19th, 20th; Meadville, 19th; Huntingdon, 7th, 8th, 19th, 20th; Kilmer, 7th, 20th; New Castle, 7th, 19th; Lebanon, 8th; Smethport, 19th, 20th; Girardville, 4th, 8th; Selins Grove, 6th, 8th, 20th; Somerset, 5th, 6th, 7th; Wellsboro, 5th, 7th, 8th, 19th, 20th, 22d, 29th, 31st; Columbus, 8th, 19th; Dyberry, 8th, 20th, 25th; Honesdale, 8th, 20th; York, 7th, 8th.

Aurorœ.—Le Roy, 7th; Quakertown, 14th; Coatesville, 13th.

Coronœ.—Blue Knob, 27th; Quakertown, 22d; Emporium, 27th; Lebanon, 21st, 22d, 23d, 30th; Philadelphia (Centennial Avenue), 22d, 30th; Dyberry, 19th.

Solar Halo.—Le Roy, 23d, 31st; Quakertown, 13th; Lock Haven, 15th; Philadelphia, 2d, 15th, 23d; Centennial Avenue, 2d, 15th, 23d; Wellsboro, 14th, 24th, 31st; Dyberry, 8th.

Lunar Halo.—Lock Haven, 20th; Meadville, 28th; Carlisle, 21st; Lancaster, 30th.

Meteors.—Meadville, 5th, 8th, 24th.

Monthly Summary of Reports by Voluntary Observers of the Pennsylvania State Weather Service for May, 1893.

County.	Station.	Elevation above Sea Level (feet).	Barometer Reduced to Sea Level.			Temperature.												Relative Humidity.	Dew Point.	Precipitation.				Number of Days.			Wind.			Observers.
			Mean.	Highest.	Lowest.	Mean.	Maximum.		Minimum.		Mean of Maximum.	Mean of Minimum.	Daily Range							Total Inches.	Total Snowfall During Month.	Depth of Snow on Ground at End of Month.	Number of Days Rainfall.	Clear.	Fair.	Cloudy.	Prevailing Direction			
							Highest.	Date.	Lowest.	Date.			Mean.	Greatest.	Date.	Least.	Date.										7 A. M.	2 P. M.	9 P. M.	
Allegheny,	Pittsburgh, A.	820	29·92	30·35	29·46	59·6	85	22	38	7	69·7	49·5	20·2	36	20	5	17	74·0	51·3	4·50	...	...	18	7	11	13	NW	NW	NW	O. D. Stewart, Weather Bureau.
Berks,	Hamburg,	380	...	...	...	59·9	88	23	38	20	70·7	49·2	21·5	42	20	3	16, 17	...	...	6·80	...	...	12	5	15	11	NW	W	SW	William Shupe
Berks,	Reading, A.	280	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	4·44	...	...	...	...	...	...	...	...	...	Franklin Yager
Blair,	Altoona, B.	1,181	...	...	...	62·5	89	24	40	8	71·8	53·2	18·6	37	24	10	27	...	...	4.67	...	...	14	...	...	...	...	...	...	Dr. C. B. Dudley
Blair,	Blue Knob, A.	2,500	...	...	...	57·0	82	22	28	7	63·9	50·2	13·7	32	7	3	16, 17	...	...	9·20	...	...	18	9	10	12	NW	NW	NW	A. H. Boyle.
Blair,	Hollidaysburg,¹	947	...	...	...	58·4	89	20	29	8	72·3	42·5	29·8	57	20	8	17	...	...	5·23	...	...	17	13	10	8	NW	W	W	Prof. J. A. Stewart.
Bradford,	Wysox¹ (26 days),	718	29·91	30·40	29·31	58·8	89	23	32	20	69·2	43·1	26·1	47	20	8	16	79·0	50·9	3·05	...	...	8	10	2	14	NW	NW	NW	Charles Beecher.
Bradford,	Le Roy,	1,400	...	...	...	55·6	84	23	36	8	65·1	46·1	19·0	33	20	4	18	...	...	7·76	...	...	13	9	11	11	SW	SW	SW	G. W. T. Warburton
Bucks,	Forks of Neshaminy¹ (26 days),	304	...	...	...	58·1	...	...	...	...	...	...	...	...	...	...	...	...	...	4.22	...	...	10	10	10	6	W	E	W	J. C. Hillman.
Bucks,	Quakertown,¹	536	29·95	30·36	29·43	57·3	86	23	36	8	69·1	46·8	22·3	37	23	7	27	76·6	49·8	5·41	...	...	14	11	9	11	SW	NW	SW	J. L. Heacock.
Cambria,	Johnstown, A.	1,184	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	E. C. Lorentz.
Cameron,	Emporium, A.	1,050	29·89	30·36	29·23	56·8	89	23	31	8	69·4	44·2	25·2	48	20	8	17	75·0	49·9	4·99	...	...	19	7	10	14	W	...	W	T. B. Lloyd.
Carbon,	E. Mauch Chunk,	550	...		...	58·5	89	23	37	10, 20	69·0	47·4	22·2	43	10	4	17	...	...	6·68	...	.	10	13	6	12	W	W	W	F. C. Wintermute.
Centre,	State College¹— Agricultural Experiment Station,	1,191	29·85	30·33	29·28	57·4	85	23	31	4	67·2	45·8	21·4	40	20	8	3, 17	72·1	47·6	6·46	...	...	15	8	7	16	W	SW	W	Prof. Wm. Frear
Chester,	West Chester,¹	455	29·90	30·34	29·34	59·2	86	23	42	4, 8	68·7	50·0	18·7	32	20	6	27	68·0	48·4	4·18	...	...	14	17	3	11	W	NW	SE	J. C. Green, D.D.S.
Chester,	Coatesville,¹	380	...	...	...	59·8	87	21, 23	35	8	71·1	47·4	23·7	42	20	7	27	...	...	3·86	...	...	11	13	8	10	W	W	W	W. T. Gordon.
Chester,	Kennett Square, A,²	275	...	...	...	57·7	...	...	...	...	...	...	...	...	...	...	...	...	...	3·61	...	...	9	16	6	9	NW	...	SW	B. P. Kirk.
Chester,	Phœnixville, A.	190	29·92	30·38	29·38	60·4	87	21, 23	39	8	70·2	50·5	19·7	35	20	6	1	72·1	51·2	4·64	...	...	12	13	6	12	NW	...	NW	Knowles Croskey
Chester,	Westtown,	350	...	...	...	58·0	87	23	30	1	68·6	47·5	22·1	47	21	6	27	...	...	3·15	...	...	6	20	4	7	SE	...	.	Harry Alger.
Clearfield,	Grampian,*¹	1,450	...	...	...	56·1	86	23	34	8	67·3	47·5	19·8	42	20	4	17	...	...	5·47	...	...	13	6	10	15	W	W	W	Nathan Moore
Clinton,	Lock Haven,¹	560	...	...	...	58·4	92	23	33	8	72·4	44·3	28·1	50	20	6	3	...	...	4·89	...	...	16	13	7	11	W	W	W	Prof. J. A. Robb.
Columbia,	Bloomsburg, A— State Normal School,	500	29·73	30·26	29·21	57·9	84	22	35	8	68·4	47·3	21·1	40	20	5	3	81·2	52·0	7·07	...	. .	13	8	8	15	W	...	W	Prof. J. G. Cope.
Crawford,	Meadville— Divinity Hall,¹	1,200	...	...	...	55·2	85	22	34	7	67·6	45·3	22·3	33	29	5	17	76·4	49·0	7·48	...	..	13	6	7	18	SW	W	SW	Chas. Graves
Crawford,	Saegertown, A.	1,200	...	...	...	53·5	82	22, 23	30	8, 19	66·5	40·5	26·0	45	22	0	17	...	...	8·89	...	...	12	9	9	13	NW	...	NW	J. G. Apple
Cumberland,	Carlisle,¹	480	...	...	...	58·1	88	21, 23	31	8	72·7	48·1	24·6	41	11	6	17	...	...	5·49	...		12	9	10	12	S	SW	S	J. E. Pague.
Dauphin,	Harrisburg, A.	361	29·92	30·38	29·36	59·0	86	23	41	4	67·0	50·5	17·1	28	20	3	17	74·8	50·0	5·32	...	...	16	10	6	15	W	W	W	F. Ridgway, Weather Bureau.
Delaware,	Swarthmore, A— Swarthmore College,	190	29·89	30·33	29·34	61·2	88	22	43	10, 11	70·9	51·5	19·4	36	21	4	17	75·0	51·0	3·48	...	...	8	6	18	7	NW	...	SW	Prof. Susan J. Cunningham.
Erie,	Edinboro,*¹	1,400	...	...	...	53·0	75	8, 22	35	5, 8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	C. F. Sweet.
Erie,	Erie, A.	681	29·89	30·31	29·34	54·0	85	23	38	6	62·0	46·0	16·0	36	23	4	17	73·0	45·0	7·99	...	...	14	7	11	13	W	W	W	P. Wood, Weather Bureau.
Fayette,	Uniontown,¹	1,000	...	...	...	59·2	83	20, 22	37	19	69·0	49·5	19·5	37	20	3	17	...	...	5·68	...	...	17	10	16	5	SW	SW	NW	Wm. Hunt.
Franklin,	Chambersburg,²	618	...	...	...	59·8	88	23	38	8	...	...	...	...	...	...	...	...	...	6·24	...	..	10	12	8	11	W	...	W	G. W. Ludwig.
Fulton,	McConnellsburg,¹	875	...	...	...	59·3	88	23	35	7, 8	71·2	46·4	24·8	45	20	4	18	71·3	50·0	6·20	...	..	15	11	11	9	W	W	NW	T. F. Sloan.
Huntingdon,	Huntingdon, A— The Normal College,	650	. .	...	...	58·7	90	23	31	8	72·1	45·3	26·8	53	20	8	17	...	...	7·79	...	...	17	13	5	13	W	...	W	Prof. W. J. Swigart.
Indiana,	Indiana— State Normal School,	1,350	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	..	...	...	...	...	...	Prof. S. C. Schmucker.
Juniata,	Kilmer,*	475	...	...	...	65·4	93	23	48	4, 20	...	...	...	...	..	...	...	...	...	6·32	...	...	12	7	14	10	W	W	W	R. J. Mickey.
Lancaster,	Lancaster, A— Franklin and Marshall College,	413	29·91	30·37	29·37	58·4	86	23	37	7	69·8	47·1	22·7	39	20	5	28	71·1	48·8	6·26	...	...	13	15	6	10	W	...	W	W. E. Bushong.
Lawrence,	New Castle,¹	932	...	...	...	59·7	86	22	28	7	68·8	42·4	26·4	46	22	8	4	...	...	6·23	...	...	9	9	6	16	W	W	W	Wm. T. Butz.
Lebanon,	Lebanon, A.	458	29·90	30·36	29·36	57·4	86	21	33	8	68·5	46·3	22·2	41	20	6	17	76·8	50·0	8·05	...	...	18	11	7	13	SW	...	SW	G. W. Hayes, C. E.
Lehigh,	Coopersburg,¹	520	...	...	...	58·7	84	11, 22	39	8	68·4	49·4	19·0	34	20	3	27	...	...	5·42	...	...	13	13	8	10	NW	NW	SE	Dr. M. H. Boye.
Luzerne,	Drifton (24 days), A.	1,683	29·88	30·29	29·36	53·9	83	22, 23	32	8, 20	66·1	41·7	24·4	46	10, 11	5	17	71·0	48·0	8·94	...	...	8	10	4	10	...	...	..	J. R. Wagner.
Luzerne,	Wilkes-Barre, A.	575	...	...	...	61·6	91	12, 23	33	8	77·2	45·9	31·3	49	10	17	4	...	...	4·15	...	...	8	21	4	6	SW	...	SW	A. W. Betterly
McKean,	Smethport (29 days), A.	1,500	...	...	...	53·1	82	22	27	8	66·0	40·3	25·7	49	20	3	17	...	...	4·90	...	...	11	11	8	12	W	...	SW	Armstrong & Brownell.
Montgomery,	Pottstown,	150	...	...	...	61·7	89	21	40	9	71·7	51·7	20·0	35	11	4	27	69·3	49·8	4·80	...	...	9	18	4	9	NW	S	W	Charles Moore, D.D.S.
Montgomery,	Skippack, A (27 days),	...	...	...	...	59·6	84	21	34	7	69·4	49·8	19·6	38	10	4	18	...	...	...	...	...	...	16	4	7	W	...	...	B. W. Hambly.
Northampton,	Easton— Lafayette College,	325	..	...	...	58·9	86	23	37	7	68·7	49·1	19·6	31	23	6	3, 27	...	...	4·82	...	..	9	10	7	14	...	...	..	J. W. Moore.
Perry,	Aqueduct Logania,*¹	367	...	...	...	60·4	90	23	36	20	71·5	49·4	22·1	43	20	2	17	...	...	6·40	...	...	13	11	10	10	S	...	..	Richard Ca[illegible]
Philadelphia,	U. S. Weather Bureau, A.	117	29·91	30·38	29·36	61·0	89	23	43	4	69·6	52·3	17·3	29	2	5	3	65·0	48·0	2·92	...	...	8	12	6	13	SW	SW	SW	L. M. Dey, Weather Bureau.
Philadelphia,	1529 Centennial Avenue, A.	120	29·91	30·38	29·35	61·4	89	23	44	3, 8	70·9	52·0	18·9	30	2	5	27	67·0	48·3	3·12	...	...	8	15	5	11	SW	...	SW	John Comly.
Philadelphia,	3911 Locust Street, A.	...	...	...	...	60·8	88	23	43	5	70·2	51·4	18·8	30	11	6	3, 27	...	...	3·37	...	...	11	11	5	15	SW	...	SW	Ralph L. Paddock.
Pike,	Blooming Grove,*¹	...	...	...	...	57·1	88	22	39	7	...	...	...	...	...	...	...	...	...	6·72	...	...	7	...	...	...	...	...	...	John Grathwohl.
Schuylkill,	Girardville (28 days),	1,000	29·84	30·31	29·29	57·8	85	23	37	8	68·1	45·5	21·6	37	20	5	17	..	...	8·51	...	...	10	12	7	9	W	NW	NW	E. C. Wagner.
Snyder,	Selins Grove, A.	455	29·92	30·38	29·35	59·4	90	23	33	8	70·4	48·3	22·1	38	22	7	10	92·2	54·2	6·85	. .		14	0	19	12	SW	...	SW	J. M. Boyer.
Somerset,	Somerset,¹	2,250	...	...	...	54·7	83	11, 22	31	7	67·6	45·6	22·2	48	20	5	17	89·1	37·1	7·30	...	...	18	9	5	17	SW	SW	SW	W. M. Schrock
Tioga,	Wellsboro,*	1,327	...	...	...	50·9	84	23	26	8	61·3	38·2	23·1	...	...	...	...	...	...	6·58	...	...	13	7	3	21	N	S	W	H. D. Dem[illegible]
Union,	Lewisburg, A.	450	29·88	30·28	29·40	57·6	86	22, 23	31	8	69·7	45·5	24·2	46	20	7	17	91·2	53·8	6·42	...	...	11	10	10	11	SW	...	SW	Prof. W. G. Owens.
Warren,	Columbus,	1,410	...	...	...	.	...	...	...	...	...	...	...	...	.	...	...	...	...	...	...	...	...	...	...	...	...	...	.	Wm. Loveland.
Wayne,	Dyberry,	1,100	...	...	..	54·4	86	23	31	20	65·0	45·0	20·0	47	20	3	4, 16	...	...	6·21	...	...	12	7	10	14	W	W, NW	W, NW	Theodore Day
Wayne,	Honesdale,	1,000	...	...	...	55·7	85	23	33	8	65·6	45·9	19·7	36	11	4	4	...	...	5·70	...	...	12	...	...	...	...	...	...	John Torrey.
Wayne,	(Salem Corners) Hamlinton,¹	1,600	...	...	...	54·4	88	23	34	8	63·7	48·1	15·6	34	23	2	4	...	...	5·21	...	...	10	6	10	15	W	W	W	T. B. Orchard, M.D.
Westmoreland,	(Immel Reservoir) Lycippus,*¹	1,420	...	...	...	58·1	78	22	45	7, 24	...	...	...	...	...	...	...	...	...	5·60	...	...	12	...	...	...	...	...	.	M[illegible] Forbes
Westmoreland,	Ligonier (27 days),	1,750	...	...	...	55·9	87	23	30	19	69·0	41·8	25·2	50	20	5	17	...	...	6·13	...	...	16	8	12	7	...	...	...	J. T. A[illegible]
Wyoming,	South Eaton, A.	660	...	...	.	56·6	82	21	33	8	67·0	46·2	20·8	40	20	7	14	...	...	5·12	...	...	9	13	3	15	S	...	NW	E. M. Ha[illegible]
York,	York, A.	385	29·87	30·27	29·34	59·7	88	23	35	8	71·6	47·8	23·8	43	20	8	17	83·8	53·2	6·53	...	...	15	15	5	11	NW	...	NW	Mrs. L. H. Grenewald.

A, Observations taken at 8 A. M. and 8 P. M. B, Observations taken at 12 Noon. * Extremes from dry thermometers. ¹ Mean temperatures, 7 + 2 + 9 + 9 ÷ 4. ² Mean of 8 + 8 ÷ 2. ³ Mean of 7 + 7 ÷ 2. Absence of numerals indicates that mean of temperature is from maximum and minimum readings.

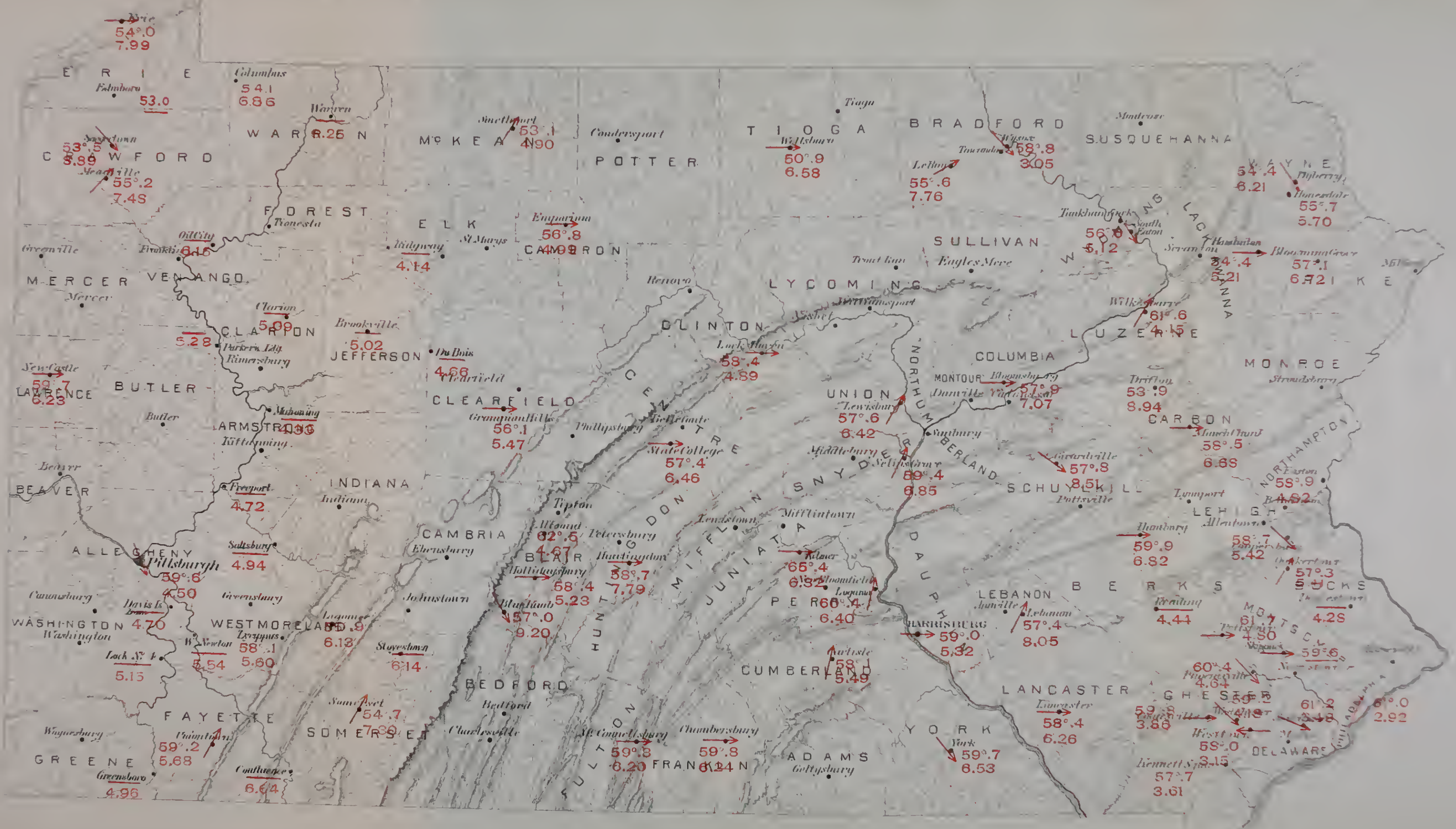
PRECIPITATION DURING MAY, 1893.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total.
Delaware Basin.																																
Blooming Grove,	·24			2·40		·25								·22		[illegible]						1·50			·18							6·72
[illegible]wers Lock,			[illegible]	[illegible]		·40										·61								·42				·10				4·08
[illegible]	[illegible]			[illegible]	·22	·26								·05	·11	·20					·03		·88					·14				3·86
Coopersburg,	[illegible]	·10	[illegible]	[illegible]	·03	·42								·25	·05	1·02					·01		·16			·02		·10				5·42
[illegible]town,	[illegible]		1·00	[illegible]		·28										1·55								·27				·04				4·28
[illegible]erry,	[illegible]	·10	·28	1·40										·28		·25	·50	·37					1·25			·40				·76	·21	6·21
[illegible]	·30			[illegible]		·60								·21		1·03	·01							·31			·05	·15				4·82
Forks of Neshaminy,	[illegible]	·02	·84	·64		·52										1·00		·02						·49			·02	·08				4·22
Frederick,	[illegible]	·02	·90	1·33		·52								·09	·04	·54							·28				·05	·05				4·51
Hamburg,	[illegible]	·26	·95	[illegible]		·81								·24		·96	·01				·14		·96			·18	·20					6·82
Honesdale,	[illegible]		[illegible]	[illegible]	·06	·08								·25		·77	·05	·01					·82			[illegible]				·53		5·70
Kennett Square			·80	1·04		·60								·05	·03	·42								·52			·04	·11				3·61
Lansdale	[illegible]	·08	[illegible]	[illegible]												1·32								·25			·04					3·59
Mauch Chunk,	[illegible]	[illegible]	·20	[illegible]		·56								·03		1·11	·05							[illegible]		·05						6·68
[illegible]sville,			2·20	[illegible]		·46								·02		1·29							·20				·15	·06				4·85
Philadelphia, a†	[illegible]		·59	·69		·47										·67								·26			·04	·19				2·92
[illegible]a,	·03		·83	[illegible]		·49										·76		·02									·05	·16				3·12
Philadelphia, c,	[illegible]		·85	[illegible]		·50								·01	·01	·64		·02						·28			·05	·20				3·37
P[illegible]	·13	[illegible]	[illegible]	1·83		·40								·03	·04	·48							·09	·30		·04		·10				4·64
[illegible]	[illegible]	·16	1·00	·90	·49											2·17											·17					5·04
Poc[illegible]	[illegible]		[illegible]	1·00		·45								·20	·15	·35							·35			·05						4·80
[illegible]	·44	·09	[illegible]	1·15	·10	·40								·25	·15	1·26							·18	·01		·06	·02	·04				5·41
[illegible]	·22	[illegible]	1·05	1·78		·50								·02	·01	·42	·01			·01	·01		·25	·07		·01	02	·01				4·44
[illegible]ers,	·22	[illegible]	·06	2·10	·20	·10	·02							·28	·10	·15	·52	·05	·03					·55			·23	·02				5·21
[illegible]e	[illegible]		1·36	1·96		·52										1·26							·29				·10					6·21
[illegible] Corner,	·40	·06	1·10	·70		·49										1·72							·12					·05				4·64
Swarthmore,			1·00	·60		·53								·02	·03	·65								·47			·18					3·48
West Chester	·06		1·10	1·11	·13	·43								·03	·12	·44		·01			·01		·50	·02			·07	15				4·18
Westtown,					1·75								·05		·25	·35							·60						·15			3·15
Susquehanna Basin.																																
Altoona,	[illegible]	·64	·18	*	1·10	·75							·07	·15		·66	·08				·44			·02			·09	·14				4·67
A[illegible]	[illegible]		[illegible]	·50	1·00								·15	·05	·22	1·50	·08			·15			·46			·16		·01				6·40
[illegible]rg.	·30	·71	[illegible]	2·18		·21							·07	·87		1·41	·12			·07			[illegible]			·20	·03					7·07
[illegible]e Knob,	[illegible]	·29	·62	[illegible]	·36							·22		·47	·03	·53	·56	·51		·75			·11			·19	·11	·22	·04		1·85	9·20
Carlisle	·10	[illegible]	·20	1·69		·90								·20		·91	·06	·02			·50		·12				·06					5·49
[illegible]ton,		[illegible]		3·10		·57	*							*		1·00	·70				*		·70	1·08		·11		*		*		8·94
[illegible]porium,	[illegible]	·17	·16	·63	·03							·12	·74	·95	·09	·85	·12	·02		·11	·03		·13		·04	·30	·06		·01			4·99
[illegible]ville	[illegible]		1·00	[illegible]	·73	*	*						·18	·31		1·50	·25				*		·76			·12						8·51
Grampian	·20			·92		·34						·40	·74	·38		·74	·54			·22			·52			·30	·10		·07			5·47
[illegible]sburg †	[illegible]	·28	[illegible]	1·58	·10	·67								·07	·04	1·04	·01			·10	·07		·30	·01		·04		·06				5·32
H[illegible]daysburg.	[illegible]	·05	·85	·63	·76							·07	·04	·03	·14	·67	·09			·63			·03			·26	·16			·07	·30	5·23
[illegible]gdon,	·23	·31	·61	1·21	·75	·21							·80	·41	·12	·53	·13			1·18	·20					·42	·12	·01			·55	7·73
[illegible]	[illegible]		1·10	·85	·76								·05	·01	·24	1·52				47			·18			·11	·06				·42	6·32
[illegible]caster,	·17	·07	·90	3·40		·55								·20	·04	·70					·11			·02		·02	·01	·07				6·26
Lebanon,	[illegible]	·15	·83	3·01	·11	·58							·01	·47	·04	1·05	·02			·03	·09		·91			·01	·01	·10			·07	8·05
Le [illegible]	[illegible]	·08	·10	3·16		·03								·23		1·90	·10	·02					·98			·38	·16				·15	7·76
Le[illegible]g	[illegible]		1·00	1·24	·28									·12		1·55				·11			·58			·31	·07				·70	6·42
[illegible]k Haven	[illegible]	[illegible]	1·19	1·24	·05	·08							·03	·16	·02	·50	·08			·15			·11			·31	·07				·38	4·87
[illegible] Grove	·21	[illegible]	·17	3·57		·30								·20	·02	1·13				·22	·01			·11		·19	·14				·13	6·85
S[illegible] Ea[illegible],	[illegible]		·31	2·29										·14		1·23	·03						·34			·29	·14					5.12
State College,	[illegible]	·17	[illegible]	1·38	·32	·03							·26	·15	·02	·95	·09			·26			·02			·18					1·18	6·46
W[illegible]	·12	·10	·08	2·10		·04								·65		2·16	·20			·02			·85			·16	·02				·08	6·58
W[illegible]kes-Barre	[illegible]		·06	1·05	·20									·11			·05						·53			·15						4·15
W[illegible],	*	*	*	*	*							·12				1·82	·48						·56			·46	·12			·16	·33	3·05
York,	·12	[illegible]	·75	1·75	·32	·46								·01	·09	1·70	·01				·22		·40			·04		·26			·75	6·53

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total.
Ohio Basin.																																
Brookville,	·61	·24		·52	·03	·07							·05	·97	·06	·02	[illegible]	·04			·28			·16			[illegible]	[illegible]				[illegible]
Clarion,	·50	·28		·11		·09								1·22	·07	·16	1·60	·08			·20			[illegible]		·02	[illegible]	[illegible]				[illegible]
Columbus,	·72			·07									·04		1·21	2·10	1·09	·02		·20			·44									[illegible]
Confluence,	·13	·23	·21	·74	·01	2·25								·35	·05	·30	·65	·20	·01		·98	·16		·20								[illegible]
Davis Island Dam,	·78	·00				·50							·12	·09	·06	·34	1·05	·08		1·08	·01			·25			·21					[illegible]
DuBois,	·50	·21	·09	·34	·04	·09							·39	·96		·04	1·09	·09			·21			·34		·02	·25					[illegible]
Freeport,	·67	·15		·08		·69								·21	·64	·16	1·25	·15			·68	·02		·39			[illegible]					[illegible]
Greensboro,		·12	·06	·19		·90							·05	·33		·50	·75	·25			1·60	·10		·10			[illegible]					[illegible]
Immel Reservoir,	·31			·48	·62									·40			1·25	·72		·67	·47		·21			[illegible]		20			[illegible]	[illegible]
Indiana,																																[illegible]
Johnstown,	1·01	·03	.52	·48	·55	·22						·35	·02	·19	·20	·78	·93	·08		40	·05		·09			19	[illegible]				[illegible]	[illegible]
Ligonier,	·21	·11	·54		·59			*	*	*	*	·07	·28	·11	·15	1·42	·45	·02		[illegible]	·09		·28			·16						[illegible]
Lock No. 4,	·38	·32	·02	·08		·53							·08	·20	·02	·30	·95	·38	·02		·75	·13		·55			12	·11			[illegible]	[illegible]
Mahoning,	·61	·18		·07	·03	·32								[illegible]	·01	·16	1·32	·03			·34	·03		·38			·29	·05				[illegible]
Meadville,	·90											·17	·35	·17	·47	3·32	1.27	·05		·30			20			24	·05				[illegible]	[illegible]
New Castle,	1·62				·28							·18	·33			·90	2·24			·20			·32			·15						[illegible]
Oil City,	·82	1·16		·05									·04	·74	·15	·36	2·13	·03			·17		19			·32						[illegible]
Parker's Landing,	·67	·49		·05		·32							·68	[illegible]	·08	2·10	·02			·29			30		·03	[illegible]	13					[illegible]
Pittsburg,†	·56			·02	·51	01						·14	09	·02	·10	·99	·55	·03		1·02	·02		·13			·16	[illegible]					[illegible]
Ridgway,	·40		·32									·72	·80	·11		·82	·01			·16			·45			[illegible]	·05					[illegible]
Saegertown,	·89											·20	·45	·02	1·49	3·20	1·96	·06		·30						·25	·01				[illegible]	[illegible]
Saltsburg,	·60	·11		·12		·83								·13	·08	·30	·95	·22	·03		·82			·54			15					[illegible]
Smethport,	·90			·70								·60	·75			·70	·10			·15			45			30	10				[illegible]	[illegible]
Somerset,	·65	·17	1·00	·55	1·00							·15	·10	·05	·35	·40	·50			·65	·52		·20			·10	·05					[illegible]
Stoyestown,	·30	·47	·22	1·13	·15	·80							·12	·19	·16	·33	·20	·16		·63	·57		·12	[illegible]			[illegible]					[illegible]
Uniontown,	·22	·05	·23	·08	1·05	·03							·17		·10	1·14	·57	·18		·98	·42		·25			·06	[illegible]					[illegible]
Warren,	1·18	·73		·26									·03	·78	·35	·32	1·72	·07			·10			[illegible]			·33	·04				[illegible]
West Newton,	·50	·45		·10		·48								·20	·02	·25	1·01	·50	·02		·62	·05		·65			·13			[illegible]		[illegible]
Potomac Basin.																																
Chambersburg,		·21		1·75	·97								·50			1·05					·83		·57					[illegible]		[illegible]		[illegible]
McConnellsburg,	·39		·90	·83	·78	·16							·42	.07	·20	·70				·40	·74		·22			·06						[illegible]
Lake Basin.																																
Erie,†	·84				·01	·03						·18	·13	·12	·18	3·68	2·33	·14					·16			.06	[illegible]					[illegible]

† U. S. Weather Bureau Stations. * Missing.

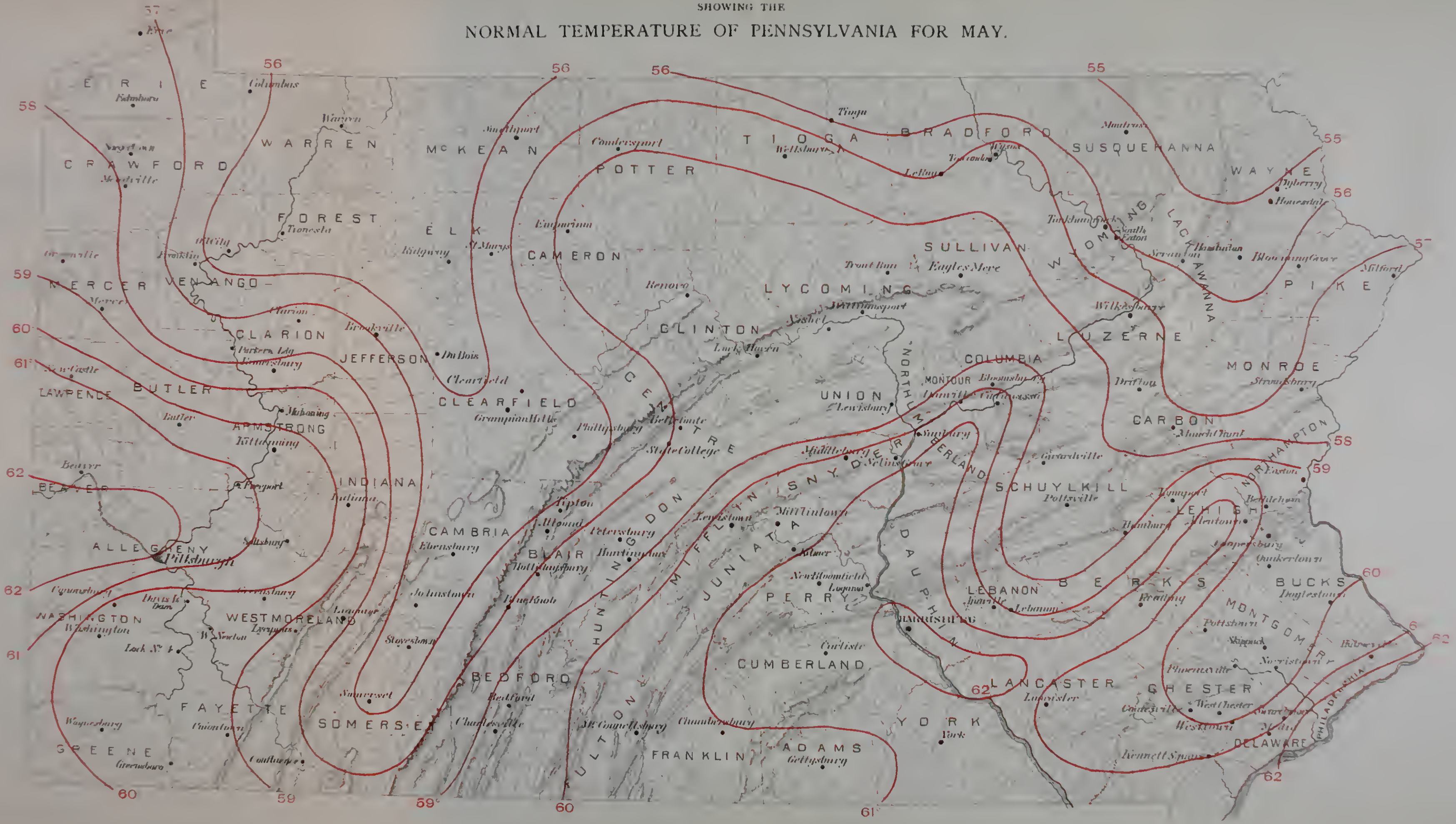
MEAN TEMPERATURE, RAINFALL AND PREVAILING WIND DIRECTION FOR MAY 1893



Jour. Frank. Inst., Vol. CXXXV May, 1893.

State Weather Service

ISOTHERMAL LINES,
SHOWING THE
NORMAL TEMPERATURE OF PENNSYLVANIA FOR MAY.



PENNSYLVANIA STATE WEATHER SERVICE,

UNDER THE DIRECTION OF THE FRANKLIN INSTITUTE,

CO-OPERATING WITH THE

UNITED STATES DEPARTMENT OF AGRICULTURE, WEATHER BUREAU.

H. L. BALL, WEATHER BUREAU, OBSERVER IN CHARGE.

MONTHLY WEATHER REVIEW.

FOR JUNE, 1893.

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, June 30, 1893.

GENERAL REMARKS.

The normal temperature of Pennsylvania for June is about 68°·9, and the normal rainfall 4·26 inches. June 1893 is noteworthy because of the wide range in the temperature. The month opened cool, but the temperature did not vary greatly from the normal until the latter part of the second decade, when the increasing warmth culminated in the fierce heat of the 19th, 20th and 21st. June 20th was perhaps the warmest June day ever recorded. The warm weather was followed by a period of cool weather which continued through the month. As an illustration of the great changes in temperature, it may be noted that at Philadelphia the mean temperature for the day on the 20th was 13° above the normal, while on the 26th it was 15° below—a range in mean daily temperature of 28° within a week. The period of warm weather closed with generous rains, which were badly needed, none of consequence having fallen within the previous ten days.

The monthly rainfall was below the normal in nearly every section and was especially deficient in the Lehigh Valley, the central northern counties and in the area draining southward into the Potomac River. In these sections the drouth very seriously affected the crops, particularly the hay crop which was materially shortened. In the Allegheny River Valley and at some stations in Bucks and Montgomery Counties the rainfall was above the normal, the excess in the latter section being due to heavy local thunder showers. General rains occurred on the 2d, 6th, 21st to 23d and 25th to 27th, the last two periods giving the greater part of the months rain.

Excessive precipitation (one inch in one hour or two and one-half inches in twenty-four hours) was recorded :

Smith's Corner, 2·65 inches, 24 hours, 22d.

Forks of Neshaminy, 1·44 inches, 0.50 minutes, 22d.

Kennett Square, 1·25 inches, 0.17 minutes, 22d.

From January 1, 1893, to June 30, 1893, the deficiency in temperature at Philadelphia was 333°, at Erie 332°, and at Pittsburgh 321°.

For the same period the excess in precipitation at Philadelphia was 1·58, at Erie 4·80, and at Pittsburgh 1·99 inches.

	Mean Temperature.	*Mean Precipitation. Inches.*
June, 1888, ...	68°·6	3·04
1889, ...	66°·5	5·43
1890, ...	70°·3	3·42
1891, ...	68°·7	4·50
1892, ...	71°·7	5·64
1893, ...	69°·6	3·12

TEMPERATURE.

The mean temperature for June, 1893, was 69°·6, which is about 0°·7 above the normal, and 2°·1 below the corresponding month of 1892.

The mean of the daily maxima and minima temperatures, 80°·7 and 58°·8, gives an average daily range at 21°·9 and a monthly mean of 69°·8.

Highest monthly mean, 76°·0 at Kilmer.

Lowest monthly mean, 63°·8 at Wellsboro.

Highest temperature recorded during the month, 100° on the 20th at Hamburg, Lock Haven, Carlisle, Aqueduct and Blooming Grove.

Lowest temperature, 38°·0 on the 20th and 21st at Drifton and 20th at Smethport.

Greatest local monthly range, 56° at Quakertown and Drifton.

Least local monthly range, 28° at Erie.

Greatest daily range, 47° at Hollidaysburg on the 19th.

Least daily range, 3° at Drifton on 3d, Coopersburg on 26th and Carlisle on 27th.

BAROMETER.

The mean pressure for the month, 30·00 is about 03 above the normal. At the United States Weather Bureau Stations the highest observed was 30·32 at Harrisburg on the 8th, and the lowest 29·56 at Philadelphia on the 22d.

PRECIPITATION.

The average rainfall 3·12 inches is a deficiency of about 1·14 inches. The largest totals reported in inches were Clarion, 6·50; Parker's Landing, 6·41; Columbus, 5·61; Frederick, 5·28; Smith's Corner, 5·08 inches.

The smallest were Blooming Grove, 1·20; Westtown, 1·30: Wellsboro, 1·42 and Wilkes-Barre, 1·43 inches.

WIND AND WEATHER.

The prevailing wind was from the West.

Average number: Rainy days, 9; clear days, 10; fair days, 11; cloudy days, 9.

MISCELLANEOUS PHENOMENA.

Thunder-storms.—Blue Knob, 2d, 3d, 4th, 15th, 20th, 25th; Hollidaysburg, 4th, 19th, 26th; Le Roy, 22d, 25th; Forks of Neshaminy, 22d; Quakertown, 6th, 22d; Johnstown, 2d, 3d, 4th, 20th, 21st, 22d, 25th; Emporium, 21st, 22d; State College, 21st, 22d, 25th; Coatesville, 6th, 11th, 21st, 22d, 26th; Kennett Square, 4th, 6th, 11th, 21st, 22d, 26th; Phœnixville, 11th; Grampian, 25th; Lock Haven, 21st, 25th; Bloomsburg, 20th, 21st, 22d, 25th; Meadville, 3d, 16th, 21st; Saegertown, 16th, 25th; Carlisle, 2d, 4th, 22d, 26th; Harrisburg, 22d, 25th, 26th; Edinboro, 2d, 3d, 10th, 15th, 16th, 17th, 21st, 22d, 25th; Uniontown, 21st, 22d, 27th, 28th; Huntingdon, 26th; Kilmer, 4th, 15th, 20th, 22d, 25th; Lancaster, 17th, 21st, 26th; New Castle, 2d, 5th, 15th, 16th, 21st, 25th, 27th; Lebanon, 15th, 21st, 22d, 26th; Smethport, 3d, 16th, 22d, 25th; Pottstown, 6th; Easton, 6th, 11th, 21st, 22d; Aqueduct, 22d; Philadelphia (Weather Bureau), 6th, 11th, 21st, 22d; (Centennial Avenue), 6th, 11th, 21st, 22d, 26th; (Locust Street), 6th, 11th, 21st, 22d; Blooming Grove, 10th, 22d, 25th; Girardville, 2d, 22d, 25th; Selins Grove, 21st, 22d, 23d, 25th; Somerset, 2d, 21st, 23d, 26th, 27th; Wellsboro, 21st, 22d, 25th; Columbus, 3d, 16th, 25th; Dyberry, 4th, 10th, 11th, 21st, 22d, 25th, 30th; Salem Corners, 21st, 22d, 25th; South Eaton, 10th, 22d, 26th, 30th; York, 22d, 26th.

Hail.—Grampian, 25th; Meadville, 21st; Saegertown, 25th; Edinboro, 25th; New Castle, 15th, 25th; Philadelphia (Centennial Avenue), 11th.

Frost.—Somerset, 24th.

Solar Halo.—Philadelphia (Weather Bureau), 7th; (Centennial Avenue), 15th; Wellsboro, 22d.

Meteors.—Quakertown, 17th.

MONTHLY SUMMARY OF REPORTS BY VOLUNTARY OBSERVERS OF THE PENNSYLVANIA STATE WEATHER SERVICE FOR JUNE, 1893.

COUNTY.	STATION.	Elevation above Sea Level (feet).	BAROMETER REDUCED TO SEA LEVEL.			TEMPERATURE.												Relative Humidity.	Dew Point.	PRECIPITATION.				NUMBER OF DAYS.			WIND.			OBSERVERS.
							MAXIMUM.		MINIMUM.		Mean of Maximum.	Mean of Minimum.	DAILY RANGE.														PREVAILING DIRECTION.			
			Mean.	Highest.	Lowest.	Mean.	Highest.	Date.	Lowest.	Date.			Mean.	Greatest.	Date.	Least.	Date.			Total Inches.	Total Snowfall During Month.	Depth of Snow on Ground at End of Month.	Number of Days Rainfall.	Clear.	Fair.	Cloudy.	7 A. M.	2 P. M.	9 P. M.	
Allegheny,	Pittsburgh, A,	820	30·01	30·30	29·66	72·0	91	19	58	8	81·6	62·1	19·5	30	19	7	11	68·2	60·2	2·87	...	...	10	10	13	7	N	N	N	O. D. Stewart, Weather Bureau.
Berks,	Hamburg,	380	...	...	...	71·8	100	20	47	29	83·3	60·7	22·6	37	19	6	16	...	...	1·63	...	...	7	5	17	8	E	W	NW	William Surpe.
Berks,	Reading, A,	280	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2·40	...	...	...	...	...	...	...	...	...	Franklin Yager.
Blair,	Altoona, B,	1,181	...	...	...	73·6	94	21	53	8, 13	83·0	64·2	18·8	28	23	10	2	...	...	2·94	...	...	9	...	...	...	...	...	...	Dr. C. B. Dudley.
Blair,	Blue Knob, A,	2,500	...	...	...	69·7	91	19, 20	54	13, 29	76·3	63·1	13·2	25	9, 19	4	29	...	...	2·49	...	...	9	2	19	9	NW	SE	SW	A. H. Boyle.
Blair,	Hollidaysburg,[1]	947	...	...	...	69·4	98	20	40	8	83·6	54·0	29·6	47	19	9	29	...	...	1·61	...	...	8	16	4	10	E	E	E	Prof. J. A. Stewart.
Bradford,	Wysox[1],	728	30·04	30·34	29·56	69·2	96	20	44	8	80·7	57·7	23·0	43	20	8	13	80·1	63·2	2·65	...	...	9	13	7	10	SE	NW	NW	Charles Beecher.
Bradford,	Le Roy,	1,400	...	...	...	67·9	94	20	50	28, 30	77·0	58·7	18·3	28	30	8	27	...	...	1·96	...	...	9	6	13	11	E	SW	SW	G. W. T. Warburton.
Bucks,	Forks of Neshaminy[1],	304	...	...	...	69·9	...	...	...	...	...	...	...	...	...	...	...	...	...	3·40	...	...	11	9	16	5	W	N	E	J. C. Hilsman.
Bucks,	Quakertown,[1]	536	30·05	30·33	29·58	68·6	98	20	42	29	81·0	56·7	24·3	37	10	7	16	79·1	62·0	2·21	...	...	8	9	13	8	NE	NE	SW	J. L. Heacock.
Cambria,	Johnstown, A,	1,184	30·02	30·29	29·67	70·3	95	20	45	8	82·9	57·6	25·3	40	8	12	6	...	...	1·93	...	...	11	7	17	6	S	...	S	E. C. Lorentz.
Cameron,	Emporium, A,	1,050	30·00	30·26	29·62	68·3	93	20	44	8, 9	79·5	57·1	22·4	41	9	5	27	82·7	61·2	4·83	...	...	7	11	11	8	E	...	W	T. B. Lloyd.
Carbon,	E. Mauch Chunk,	550	...	...	...	69·6	99	20	44	8	81·7	57·5	24·2	40	20	8	27	...	...	1·54	...	...	9	15	8	7	W	W	W	F. C. Wintermute.
Centre,	State College[1]— Agricultural Experiment Station,	1,191	29·96	30·30	29·47	68·7	92	20	46	13	77·5	58·0	19·5	34	19	8	29	75·0	59·8	3·94	...	...	9	7	8	15	S	W	S	Prof. Wm. Frear.
Chester,	West Chester,[1]	455	30·02	30·31	29·60	70·7	95	20	51	29	79·6	61·7	17·9	29	18	8	27	71·0	61·5	2·59	...	...	9	12	6	12	N	NE	S	J. C. Green, D.D.S.
Chester,	Coatesville,[1]	380	...	...	...	70·2	98	20	50	9	81·7	59·1	22·6	35	19	8	27	...	...	3·93	...	...	9	10	10	10	W	W	W	W. T. Gordon.
Chester	Kennett Square, A,[2]	275	...	...	...	68·7	83	20	57	29	...	...	...	...	...	...	...	...	...	3·46	...	...	11	10	12	8	E	...	SW	B. P. Kirk.
Chester	Phœnixville, A,	190	30·03	30·33	29·58	70·8	97	20	51	13	80·7	60·9	19·8	32	18	7	27	75·1	60·3	2·49	...	...	12	9	7	14	NW	...	NE	Knowles Croskey.
Chester,	Westtown (29 days),	350	...	...	...	69·4	95	20	53	13	79·2	59·6	19·6	31	10, 18	8	29	...	...	1·30	...	...	4	18	7	5	N	...	N	Harry Alger.
Clearfield,	Grampian,*[1]	1,450	...	...	...	68·9	94	19, 20	50	8, 13	78·4	61·4	17·0	32	20	4	6, 29	...	...	2·25	...	...	10	8	13	9	SW	E	W	Nathan Moore.
Clinton,	Lock Haven,[1]	560	...	...	...	70·4	100	20	45	8	84·8	50·7	28·1	45	9	10	27	...	...	2·51	...	...	7	14	3	13	W	W	W	Prof. J. A. Robb.
Columbia,	Bloomsburg, A— State Normal School,	500	29·88	30·21	29·51	70·8	96	20	48	8	81·3	60·2	21·1	34	20	8	27	79·3	62·4	2·93	...	...	6	6	10	14	E	...	W	Prof. J. G. Cope.
Crawford,	Meadville— Divinity Hall,[1]	1,200	...	...	...	68·2	92	5	45	8	82·1	57·9	24·2	40	8	11	26	81·3	63·2	3·21	...	...	8	6	13	11	S	SW	SW	Chas. Graves.
Crawford,	Saegertown, A,	1,200	...	...	...	67·3	91	19	42	8, 13	80·3	54·3	26·0	40	9	13	26	...	...	3·25	...	...	12	14	9	7	SE	...	NW	J. G. Apple.
Cumberland,	Carlisle,[1]	480	...	...	...	69·3	100	20	48	8	82·1	61·1	21·0	38	19	3	27	...	...	3·42	...	...	12	12	11	7	S	S	S	J. E. Pague.
Dauphin,	Harrisburg, A,	361	30·02	30·32	29·58	71·0	96	20	54	8	80·0	62·0	18·0	30	18	6	27	76·0	62·0	2·46	...	...	12	10	7	13	E	E	E	F. Ridgway, Weather Bureau.
Delaware,	Swarthmore, A— Swarthmore College,	190	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Prof. Susan J. Cunningham.
Erie,	Edinboro,*[1]	1,400	...	...	...	68·0	86	20	50	12, 13	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	C. F. Sweet.
Erie,	Erie, A,	681	29·98	30·27	29·60	68·0	89	20	51	13	75·0	61·0	14·0	21	24	8	10	73·0	59·0	3·20	...	...	14	7	14	9	W	W	W	P. Wood, Weather Bureau.
Fayette,	Uniontown[1] (26 days),	1,000	...	...	...	70·2	90	19, 20	47	8	80·4	59·0	21·4	35	8	7	6	...	...	2·34	...	...	6	15	4	2	NW	NW	NW	Wm. Hunt.
Franklin,	Chambersburg,[2]	618	...	...	...	72·4	97	18	51	7	82·3	62·6	19·7	34	17	5	5	...	...	1·80	...	...	6	...	...	...	...	...	...	G. W. Ladwig.
Fulton,	McConnellsburg,[1]	875	...	...	...	69·3	97	19	45	8, 24	82·3	57·7	24·6	42	25	10	28	81·3	61·1	1·87	...	...	6	13	10	7	W	W	W	T. F. Sloan.
Huntingdon,	Huntingdon, A— The Normal College,	650	...	...	...	68·9	98	20	43	8	81·7	55·2	27·5	45	20	9	29	...	...	2·37	...	...	11	11	7	12	W	...	W	Prof. W. J. Swigart.
Indiana,	Indiana— State Normal School,	1,350	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Prof. S. C. Schmucker.
Juniata,	Kilmer,[3]	475	...	...	...	76·0	99	20	59	27	...	...	...	...	...	...	...	...	...	2·52	...	...	12	6	17	7	W	W	W	R. J. Mickey.
Lancaster,	Lancaster, A— (29 days), Franklin and Marshall College,	413	...	...	...	70·5	95	20	52	8, 9	81·4	59·6	21·8	39	19	9	2	77·8	62·0	4·25	...	...	5	10	11	8	NW	...	NW	W. E. Bushong.
Lawrence,	New Castle,[1]	932	...	...	...	73·5	95	19	40	8	82·6	55·8	26·8	41	8, 19	4	11	...	...	4·38	...	...	10	12	8	10	SE	S	SE	Wm. T. Butz.
Lebanon,	Lebanon, A,	458	30·00	30·31	29·60	70·9	98	20	49	8	82·0	59·7	22·3	40	19	7	27	79·3	62·4	2·21	...	...	11	10	11	9	NE	...	SW	G. W. Hayes, C. E.
Lehigh,	Coopersburg,[1]	520	...	...	...	68·3	93	20	49	9	77·2	60·1	17·1	27	11, 18	3	26	...	...	2·80	...	...	11	11	8	11	SW	SW	NE	Dr. M. H. Boye.
Luzerne,	Drifton (26 days), A,	1,683	30·00	30·21	29·60	64·1	94	20, 21	38	1	77·7	50·5	27·2	44	5	3	3	76·0	57·0	1·70	...	...	4	10	5	11	...	...	...	J. R. Wagner.
Luzerne,	Wilkes-Barre, A,	575	...	...	...	71·2	96	19, 20	42	9	85·0	57·5	27·5	45	9	7	28	...	...	1·43	...	...	8	20	5	5	SW	...	SW	A. W. Betterly.
McKean,	Smethport, A,	1,500	...	...	...	65·9	91	20	38	8	78·2	53·6	24·6	41	8, 9	10	6, 27	...	...	3·68	...	...	10	11	9	10	SW	...	SW	Armstrong & Brownell.
Montgomery,	Pottstown,	150	...	...	...	72·9	98	20	51	29	82·6	63·2	19·4	31	10	8	27	72·0	61·0	3·64	...	...	9	13	13	4	NW	W	W	Charles Moore, D. D. S.
Montgomery,	Skippack, A (21 days),	...	...	...	...	70·6	94	20	49	10	81·3	59·8	21·5	38	10	5	27	...	...	...	...	...	...	10	6	5	W	...	W	B. W. Dambly.
Northampton,	Easton[1]— Lafayette College,	325	...	...	...	70·2	97	20	49	28	80·9	59·5	21·4	32	18	8	27	...	...	1·66	...	...	7	10	12	8	...	...	...	J. W. Moore.
Perry,	Aqueduct (Logania),*	367	...	...	...	73·6	100	20	52	8	84·7	62·4	22·3	40	20	7	26, 27	...	...	3·83	...	...	11	12	10	8	S	S	S	Richard Ca[illegible]
Philadelphia,	U. S. Weather Bureau, A,	117	30·01	30·31	29·56	72·0	98	20	55	1	81·4	63·1	18·3	30	18	7	26	70·0	60·0	3·07	...	...	8	6	6	18	NE	NE	NE	L. M. Dey, Weather Bureau.
Philadelphia,	1529 Centennial Avenue, A,	120	30·01	30·31	29·56	72·2	98	20	53	29	81·7	62·6	19·1	30	10, 18	6	26	71·7	60·4	3·00	...	...	8	6	15	9	NE	...	SW	John Comly.
Philadelphia,	3911 Locust street, A,	...	...	...	...	72·0	98	20	52	29	81·6	62·4	19·2	32	10	7	7	...	...	3·24	...	...	9	6	11	13	SW	...	SW	Ralph L. Paddock.
Pike,	Blooming Grove,*	...	...	...	...	68·5	100	20	54	28, 29	...	...	...	...	...	...	...	...	...	1·20	...	...	6	...	...	...	...	...	...	John Grathwohl.
Schuylkill,	Girardville[1],	1,000	29·93	30·27	29·48	68·7	94	20	41	3	78·7	57·0	21·7	34	20	11	26	...	...	2·17	...	...	7	14	7	9	W	W	W	E. C. Wagner.
Snyder,	Selins Grove, A,	455	30·00	30·33	29·61	72·0	99	20, 21	46	8	84·8	59·3	25·5	42	24	8	2	93·7	64·3	4·44	...	...	8	4	13	13	SW	...	SW	J. M. Boyer.
Somerset,	Somerset,[1]	2,250	...	...	...	67·1	93	19	44	24	76·6	57·1	21·5	40	8	4	26	91·1	66·0	2·02	...	...	5	10	9	11	SW	SW	SW	W. M. Schrock.
Tioga,	Wellsboro,*	1,327	...	...	...	63·8	92	20	44	24, 28	...	...	...	...	...	...	...	...	...	1·42	...	...	4	7	13	10	N	S	S	H. D. Dem[illegible]
Union,	Lewisburg, A,	450	30·06	30·32	29·72	70·3	96	19	45	8	81·7	†58·8	22·9	37	8	8	27	87·9	65·2	4·36	...	...	8	12	7	11	S	...	S	Prof. W. G. Owens.
Warren,	Columbus,	1,410	...	...	...	67·3	97	20	42	8	80·8	54·8	26·0	45	20	4	11	...	...	5·61	...	...	11	10	14	6	W	W	W	Wm. Loveland.
Wayne,	Dyberry,	1,100	...	...	...	65·9	95	20, 21	40	8	78·7	55·7	23·0	41	20	8	12, 16	...	...	3·06	...	...	9	9	10	11	NW	NW	NW	Theodore Day.
Wayne,	Honesdale,	1,000	...	...	...	67·4	89	20	49	29	77·7	57·2	20·5	32	20	7	16	...	...	2·20	...	...	8	...	...	...	...	...	...	John Torrey.
Wayne,	(Salem Corners) Hamlinton,[1]	1,600	...	...	...	66·3	92	20	48	8	77·1	59·6	17·5	30	8	4	26	...	...	1·80	...	...	9	7	8	15	NW	SE, W	SE, W	T. B. Orchard, M. D.
Westmoreland,	(Immel Reservoir) Lycippus,*[1]	1,420	...	...	...	68·0	88	19	58	7, 8	...	...	...	...	...	...	...	...	...	3·75	...	...	9	...	...	...	...	...	...	Murray Forbes.
Westmoreland,	Ligonier (29 days),	1,750	...	...	...	68·6	94	19	42	8	82·5	54·5	28·0	42	8, 19	9	16	...	...	3·67	...	...	10	19	7	3	...	...	...	J. T. Ambrose.
Wyoming,	South Eaton, A,	660	...	...	...	68·2	91	20	46	8	78·0	58·4	19·6	34	20	10	2, 5, 6	...	...	2·98	...	...	7	14	8	8	S	...	S	B. M. Hall.
York,	York, A,	385	29·99	30·23	29·56	71·0	98	20	50	24	82·3	59·8	22·5	39	19	6	27	84·1	63·5	2·50	...	...	9	12	11	7	SE	...	NW	Mrs. L. H. Grenewald.
	MAY, 1893. *Reports received too late for May Bulletin.*																													
	Johnstown,	...	29·94	30·38	29·47	58·5	91	23	34	7, 8	71·3	45·8	25·5	50	20	6	17	...	...	6·26	...	...	21	6	9	16	S	...	S	
	Columbus,	...	...	...	...	54·1	85	22	29	8	66·2	41·9	24·3	49	22	4	16	61·6	39·0	6·86	...	...	12	9	9	13	W	W	W	

A, Observations taken at 8 A. M. and 8 P. M.   B, Observations taken at 12 Noon.   * Extremes from dry thermometers.   [1] Mean temperatures, 7 + 2 + 9 + 9 + 4.   [2] Mean of 8 + 8 + 2.   [3] Mean of 7 + 7 + 2.   Absence of numerals indicates that mean of temperature is from maximum and minimum readings.   † 22 days.

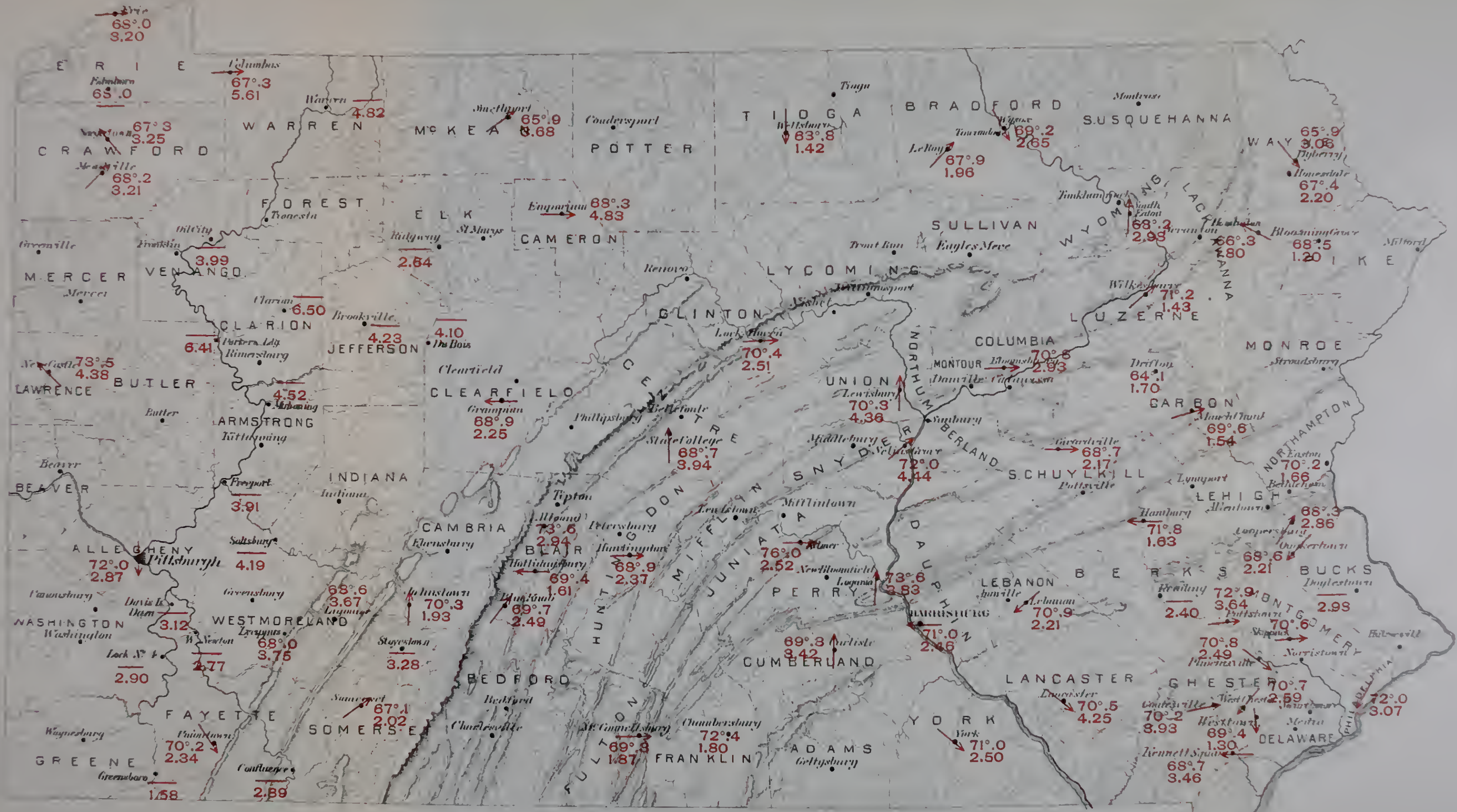
PRECIPITATION DURING JUNE, 1893.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total.
Delaware Basin.																																
Blooming Grove,						·12				·03											·25		·47		·33							1·20
Brewers Lock,			·20			·44					·08						·05					·04	·16			1·21	·04					2·22
Coatesville,		·36				1·13					·08					·03						·95	·01		·46	·79	·12					3·93
Coopersburg,		·18	·01			·30					·32					·01	·04				·03	1·18	·10		·03	·66						2·86
Doylestown,		·04				·78											·02					1·45	·11			·58						2·98
Dyberry,					·15												·07				·09	1·72	·12		·21	·53		·05		·12		3·06
Easton,				·02		·22					·15					·15						·07	·75					·30				1·66
Forks of Neshaminy,		·04	·02			·55					·07						·07				·04	1·44	·38		·05	·72		·02				3·40
Frederick,		·38				1·62				·06							·04					1·86	·19		·26	·83	·04					5·28
Hamburg,		·29				·06					·08				·02										·14	·86	·18					1·63
Honesdale,				·04		·02				·03			·02				·04				·06	1·58			·41							2·20
Kennett Square,		·39	·02	·02		·42					·10					·05					·03	1·25	·41	·12	·65							3·46
Lansdale,		·30				1·00					·58		·03								·45	·05			·05	·75						3·21
Mauch Chunk,		·08				·07											·05				·28	·20	·20		·05	·52	·09					1·54
Ottsville,		·19				1·00										·09					·06	1·30	·86			·40	·02					3·92
Philadelphia, a†		·03				·17						·28					·05					·68	1·12		·08	·66						3·07
Philadelphia, b,		·04				·20						·28					·03					·65	1·43		·08	·89						3·60
Philadelphia, c,		·05				·27						·11					·02					·80	1·26		·10	·61				·02		3·24
Phœnixville,		·39	·03			·46					·17					·02	·03				·05	·04	·09		·23	·95	·03					2·49
Point Pleasant,		·03				1·06															·64	2·27	·46			·51	·02					4·99
Pottstown,		·75				1·40					·05						·05				·15	·21	·06		·22	·75						3·64
Quakertown,		·21	·02			·77										·06	·07					·25	·07			·76						2·21
Reading,	·01	·90		·01		·27					·01					·01	·02				·02	·01	·01		·08	·80	·25					2·40
Salem Corners,			·02			·07					·10		·02				·05					·58	·50			·44	·02					1·80
Seisholtzville,		·77				·22					·20											·35			·68							2·22
Smith's Corner,		·10				1·21						·04				·04	·05				·07	2·65	·37			·55						5·08
Swarthmore,																																
West Chester,		·24				·37					·06					·03						·77	·24		·30	·57	·01					2·59
Westtown,						·60					·20											·30			·20					*		1·30
Susquehanna Basin.																																
Altoona,	1·66	·10					·02											·02			·09	·27				·40	·15		·23			2·94
Aqueduct,	·01	·21		·09											·10						·10	·50	·05		·28	2·33	·05		·11			3·83
Bloomsburg,		·03																			·34	1·09			·09	·11	1·27					2·93
Blue Knob,		·18				·09										·01					·02					·95	·84	·26	·10	·04		2·49
Carlisle,		·13		·04		·02					·02					·02	·18					1·10			·15	1·10	·48	·04	·14			3·42
Drifton,		·05		*			·10				*							*							*	1·30	·25					2·70
Emporium,		·02				·50															·81	·28			·79	1·08	1·35					4·83
Girardville,		·04				·06																·26	·14		·59	·93	·15					2·17
Grampian,				·20	·21	·12					·05					·01					·26	·52			·58	·08	·22					2·25
Harrisburg,†		·17		·04		·06										·01	·01					·14	·01		·20	1·50	·23		·08	·01		2·46
Hollidaysburg,				·12		·04										·04					·28	·13				·57	·29		·14			1·61
Huntingdon,	·04	·15		·25		·15															·37	·02	·02		·05	1·00	·21		·11			2·37
Kilmer,	·01	·04		·10		·04									·34	·03					·10	·05			·49	1·25	·06		·01			2·52
Lancaster,		1·50				·99											·03					·33				1·40			*			4·25
Lebanon,		·18				·08									·06		·01				·22	·04	·01		·26	1·05	·28		·02			2·21
Le Roy,		·03		·01		·16				·03											·10	·84			·07	·56	·16					1·96
Lewisburg,		·04				·12															·15	·81	·13		·42	1·85	·84					4·36
Lock Haven,		·05				·10															·05	·72			·72	·72	·15					2·51
Selins Grove,		·03				·02															·50	·07	·06		·71	2·39	·65	·01				4·44
South Easton,		·05			·05	·20															·64	·85				1·07				·12		2·98
State College,		·40				·12															1·19	·89	·04		·21	·72	·26		·11			3·94
Wellsboro,						·10															·30	·10			·92							1·42
Wilkes-Barre,						·05				·02										·08	·12	·20			·02	·64	·30					1·43
Wysox,		·05		·12																·10	·10	·48		·08	·50	1·00	·22					2·65
York,		·24		·56	·04	·20											·01					·22			·13	1·02			·08			2·50

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Total.
Ohio Basin.																																
Brookville,			·33		·07	·59	·23														·06	·81	·93			·33	·24	·24				[illegible]
Clarion,	·05	·04	·67	·05		1·07	·14				·02						1·65				·05	1·00	·50			·27	·02	[illegible]				[illegible]
Columbus,		·12	·52		·27	·57					·05					·70					·95	·08			[illegible]	[illegible]	·06					[illegible]
Confluence,	·34	·01	·25	·06		·20	·17									[illegible]					·04	·21	1·15			[illegible]		[illegible]				[illegible]
Davis Island Dam,	·02	·08			·54	·35	·10				·02					·04	·44				·01	·42	[illegible]			[illegible]						[illegible]
DuBois,	·09				·24	·35	·24														·11	1·45	·36		·18	·79	·11	·13				[illegible]
Freeport,			·11		·08	·87	·12				·04						·02					1·31	·52			[illegible]	·03	[illegible]				[illegible]
Greensboro,						·17	·10														·05	·50	·63			·08			·05			[illegible]
Immel Reservoir,		·34	·21			·28														·05	·43	·13	2·00			·14	[illegible]					[illegible]
Indiana,																																
Johnstown,		·23	·06		·11										·03						·54	·25	·01		·01	[illegible]	[illegible]					[illegible]
Ligonier,	·55	·17				·18									·02					·30	·50	1·07			·11	[illegible]	[illegible]					[illegible]
Lock No. 4,			·22			·61	·07								·09						·29	·08	1·39			·15						[illegible]
Mahoning,	·11	·06	·34		·24	·42	·11										·03					·91	·74			·35	[illegible]	[illegible]				[illegible]
Meadville,	·06				·30	·01										1·63					·42	·19			·50	·10						[illegible]
New Castle,	·16	·48			·20	·28									·08	·16					·10	·35			[illegible]		·09					[illegible]
Oil City,	·17	·10	·10			·17	·06										1·60					·60	·36		·02	[illegible]	[illegible]	[illegible]				[illegible]
Parker's Landing,			1·47			·69	·14										1·44				·40	·22	·71			[illegible]	·05	·33				[illegible]
Pittsburg,†		·10		·34	·31	·27									·09	·14					·22	[illegible]				[illegible]	·08					[illegible]
Ridgway,					·42	·01														·16	·62	[illegible]	·08		[illegible]	·20	·30					[illegible]
Saegertown,		·13	·01	·11	·15	·70										[illegible]	·03				·12	·11		·08	·03	·13						[illegible]
Saltsburg,			·41		·24	·40	·05									·47		·07				·50	·30			[illegible]	[illegible]	·56	[illegible]			[illegible]
Smethport,		·10	·05			·30						·05					·05				·50	·55			·33	[illegible]	[illegible]					[illegible]
Somerset,		·35																		·46	·46					·40	[illegible]					[illegible]
Stoyestown,		·21	·69	·18			·12		·10								·22				·12	·60	·26			[illegible]	·24	[illegible]				[illegible]
Uniontown,		·27				·17							*	*	*	*					·64	·99				·09	[illegible]					[illegible]
Warren,	·01		·01	·02		·32	·10										1·20	·02			·44	·22	[illegible]		·52	[illegible]	[illegible]	[illegible]				[illegible]
West Newton,			·09			·63	·05														·32	·03	1·27			·05		·30	[illegible]			[illegible]
Potomac Basin.																																
Chambersburg,						·05																·09				[illegible]	[illegible]		[illegible]			[illegible]
McConnellsburg,		·18				·15										·08										[illegible]	[illegible]					[illegible]
Lake Basin.																																
Erie,†	·02		·18	·01	·45	·07					·01					·56	·03	·02			·34	·04			1·30	·10	[illegible]					[illegible]

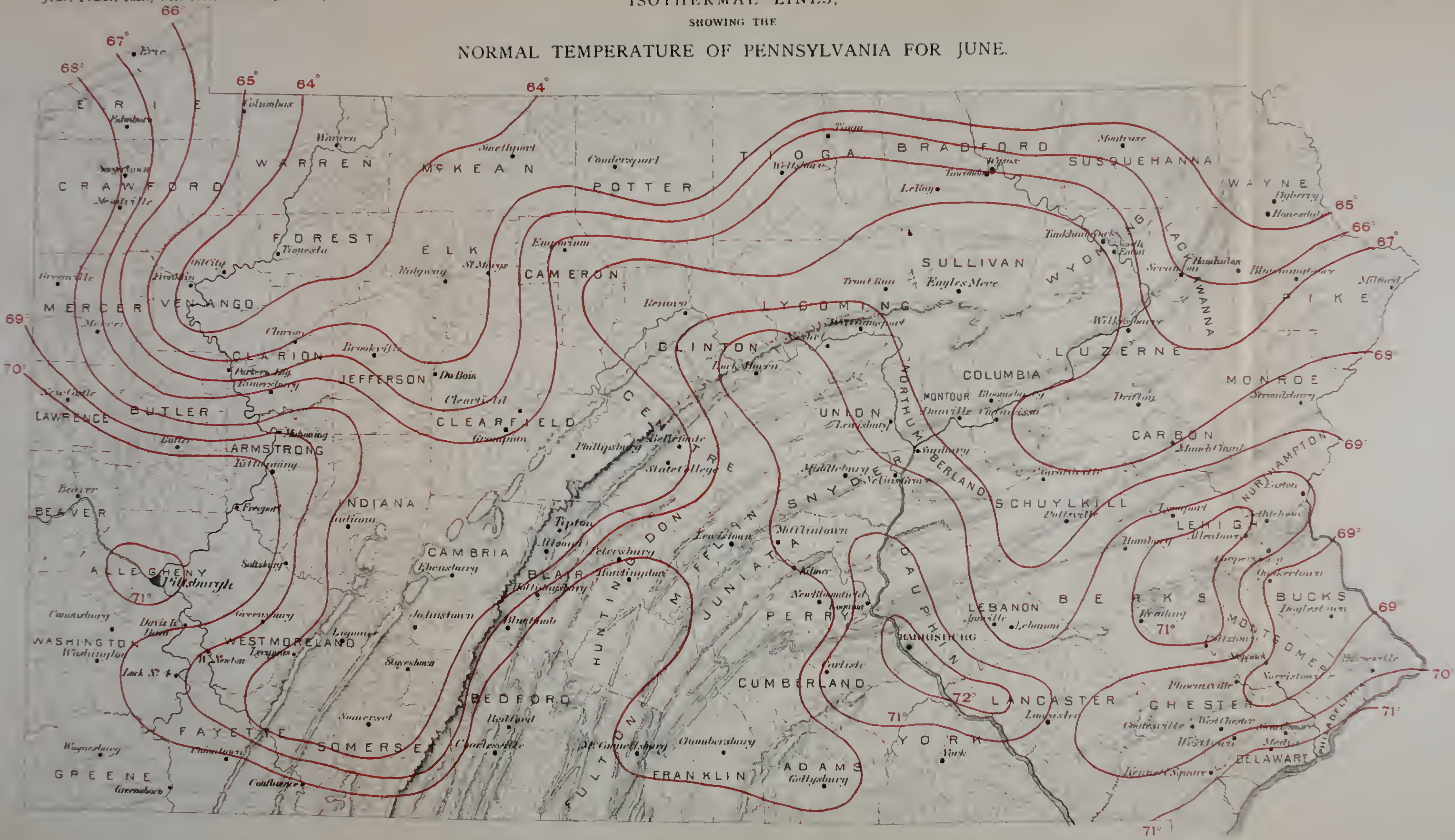
† U. S Weather Bureau Stations. * Missing.

MEAN TEMPERATURE, RAINFALL AND PREVAILING WIND DIRECTION FOR JUNE. 1893



Jour. Frank. Inst., Vol. CXXXVI. August, 1893.

ISOTHERMAL LINES,
SHOWING THE
NORMAL TEMPERATURE OF PENNSYLVANIA FOR JUNE.



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